ZIN Technologies

NASA Glenn Research Center (GRC)
Acceleration Measurement and Analysis Projects

Over a Decade of Support for the International Space Station

Kevin McPherson
Jennifer Keller
Eric Kelly
Ken Hrovat

Outline

1. Moving forward
2. Capabilities and services
3. Science support/customers
4. Microgravity community feedback model
5. Timeline of acceleration system deployment
6. Location of acceleration sensor deployment
7. Overview of ug environment & basic characterization
8. Characterize some specifics
9. Other events and disturbances

ACRONYM	Definition
ARED	Advanced Resistive Exercise Device
ATV	Automated Transfer Vehicle
BASS	Burning And Suppression of Solids
CEVIS	Cycle Ergometer with Vibration Isolation System
CIR	Combustion Integrated Rack
FIR	Fluids Integrated Rack
GRC	Glenn Research Center
HiRAP	High Resolution Accelerometer Package
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
MAMS	Microgravity Acceleration Measurement System
MSG	Microgravity Science Glovebox
NASA	National Aeronautics and Space Administration
OARE	Orbital Acceleration Research Experiment
OSS	OARE Sensor Subsystem
PCSA	Principal Component Spectral Analysis
PIMS	Principal Investigator Microgravity Services
PSD	Power Spectral Density
RMS	Root Mean Square
RTS	Remote Triaxial Sensor
SAMS	Space Acceleration Measurement System
SE	Sensor Enclosure
T2	Treadmill 2
TB	Terabytes
TSH-ES	Triaxial Sensor Head Ethernet Standalone

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Moving Forward

- **SAMS** - the Space Acceleration Measurement System:
  - has the ability to instrument and measure in all 3 ISS labs for the vibratory regime ($0.01 \leq f \leq 300$ Hz).
  - team participated in preliminary discussions and plans for measurement in the Russian segment.

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  - data can be mapped to arbitrary locations (rigid-body assumed).

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- A collaboration with the Canadian Space Agency is underway to **publish a comprehensive characterization of the acceleration environment of the ISS for the first year of assembly complete** based on SAMS and MAMS measurements.

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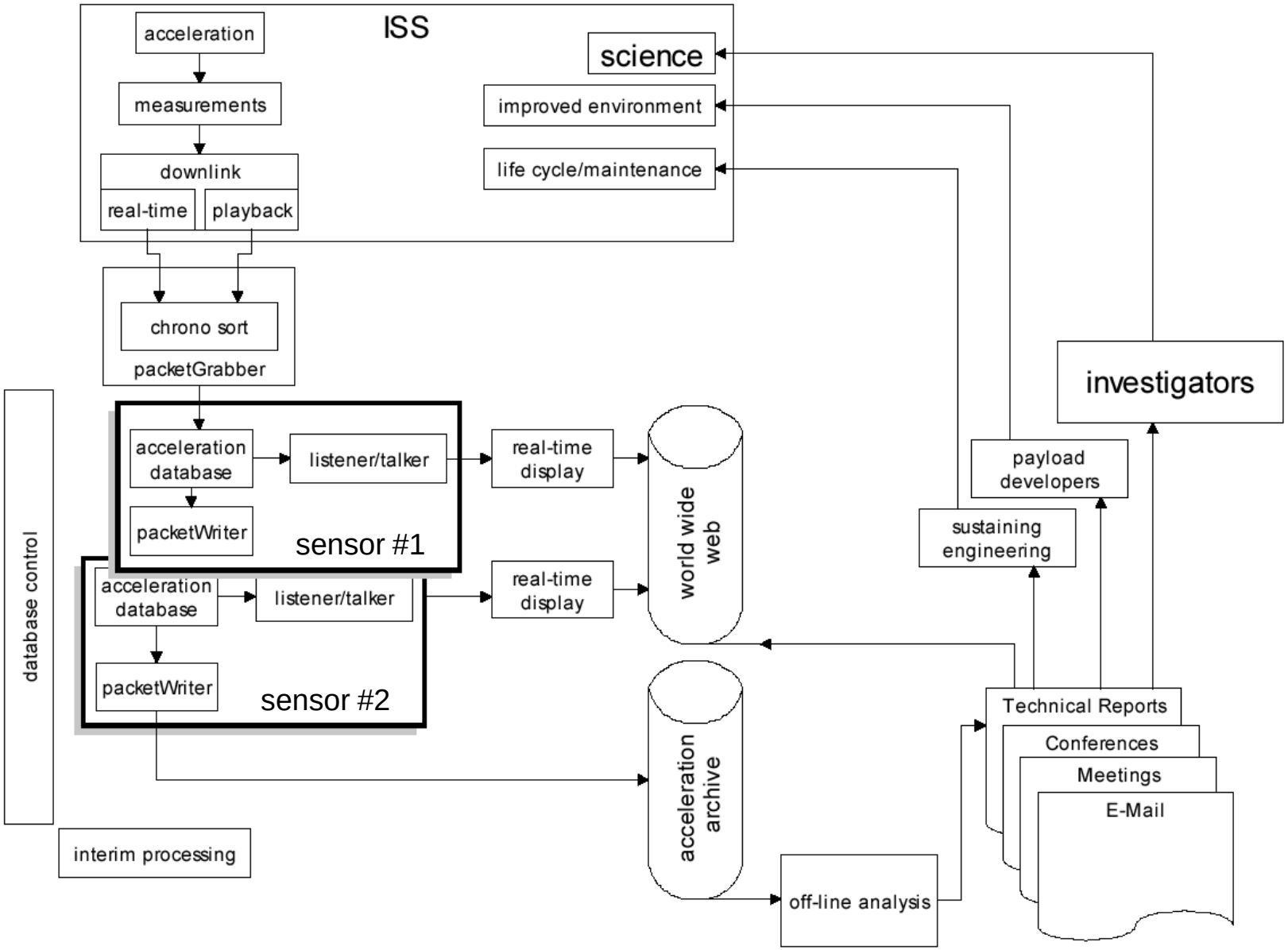
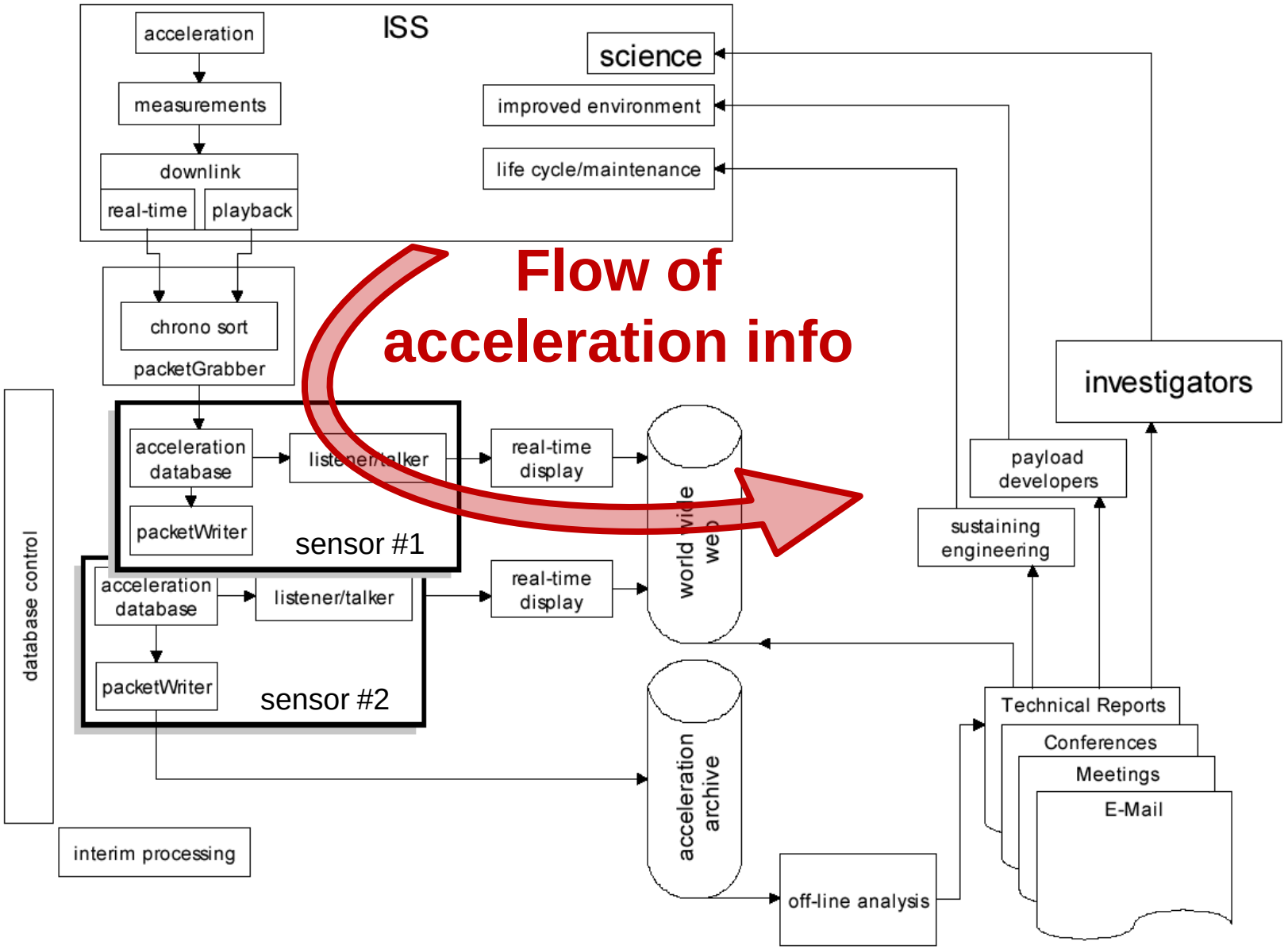
Capabilities and Services

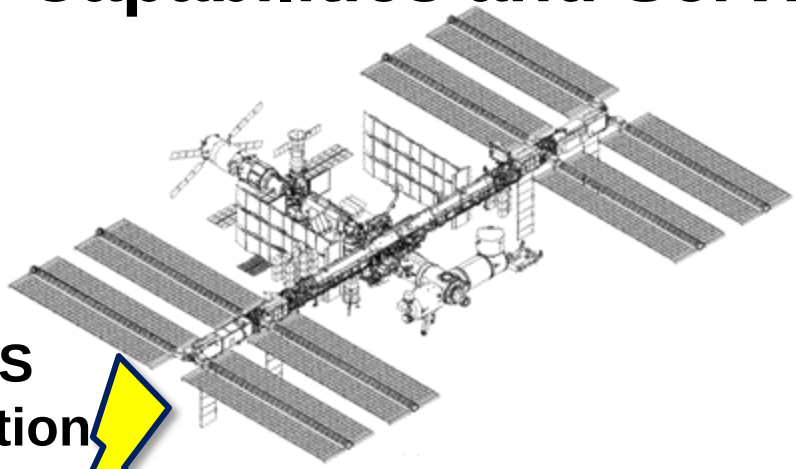


ZIN Technologies

Capabilities and Services

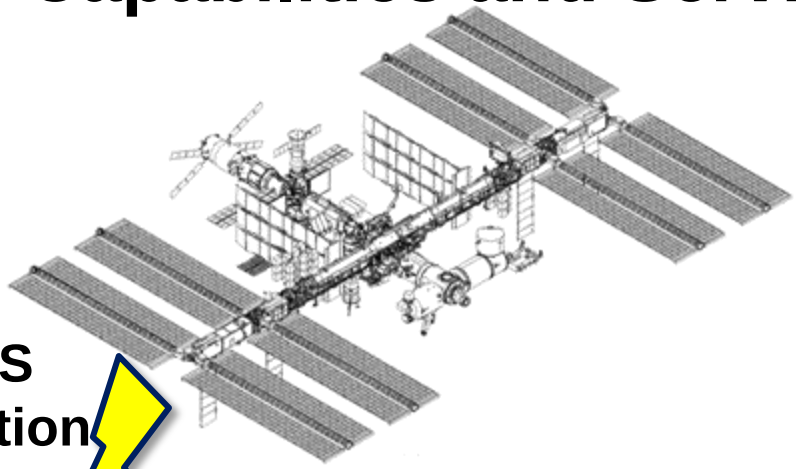


Capabilities and Services



SAMS & MAMS stream acceleration data 24x7

Capabilities and Services



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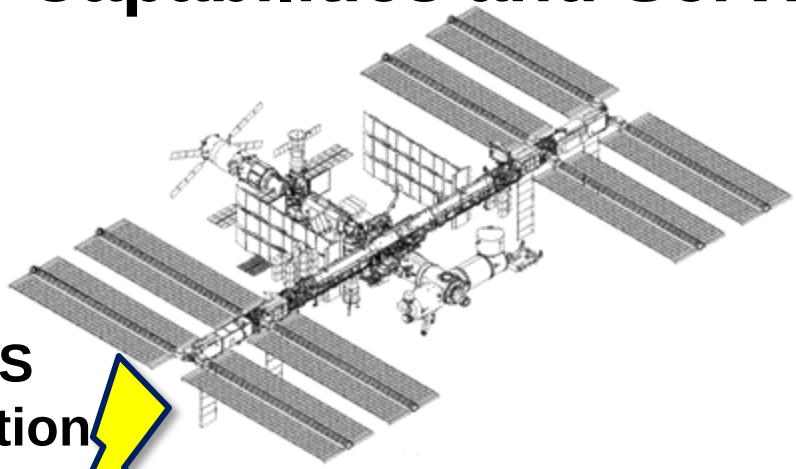

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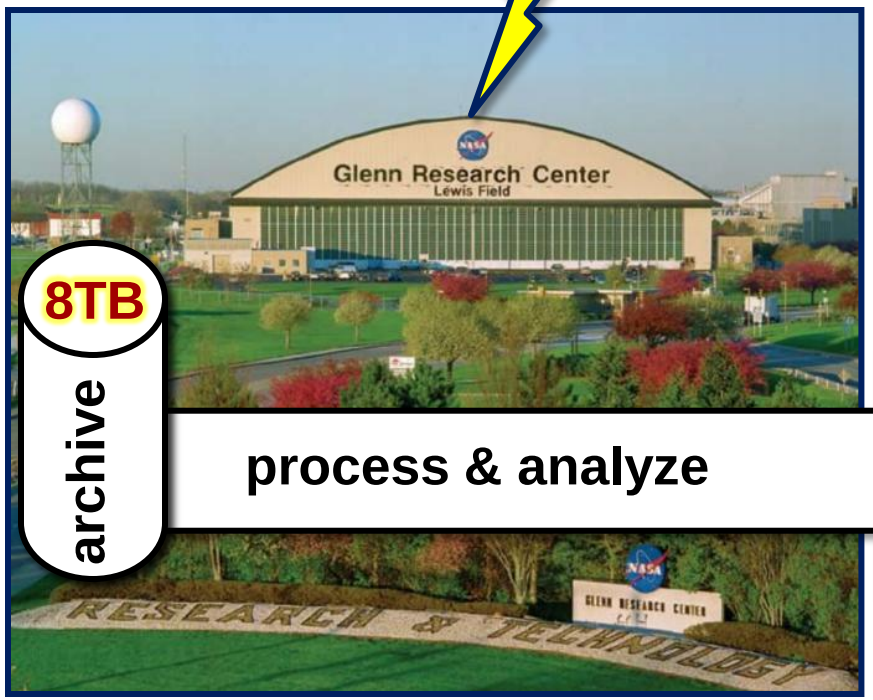

http://pims.grc.nasa.gov

web access: near real-time displays, data archives, tailored off-line requests

pimsops@grc.nasa.gov

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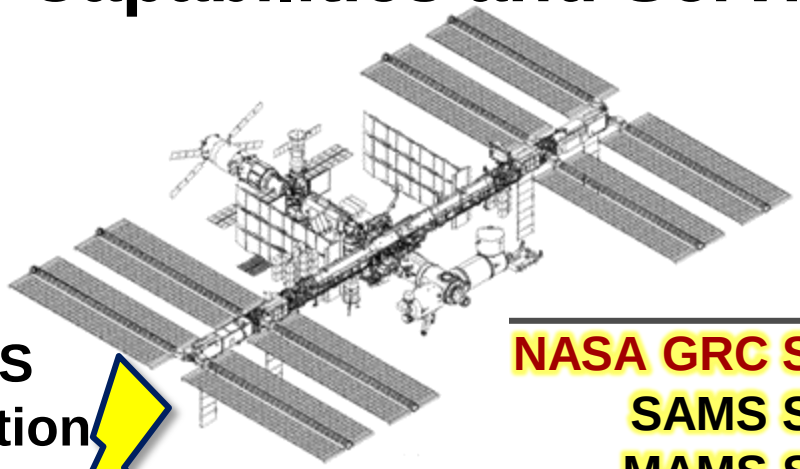
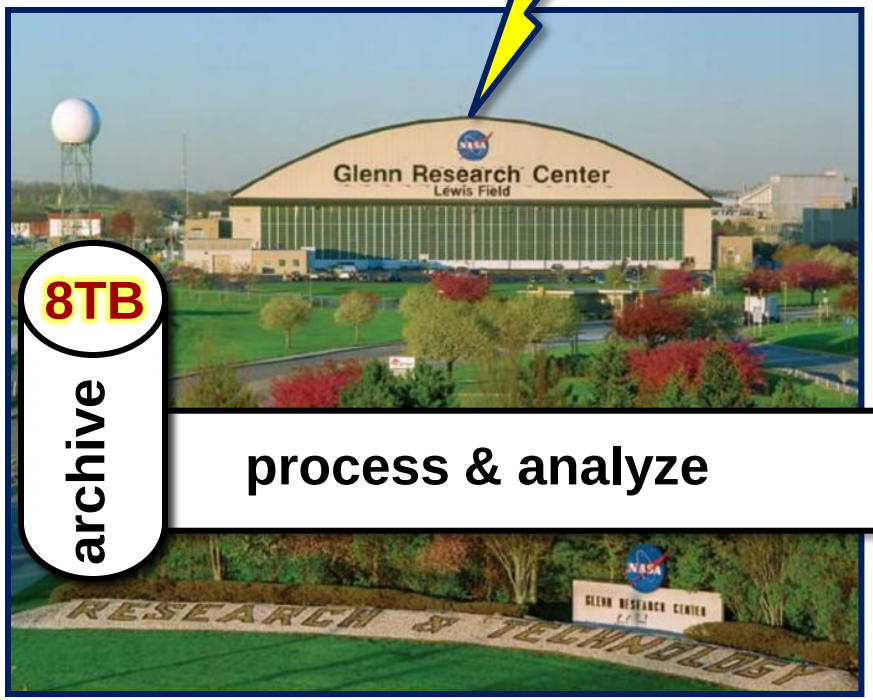
Capabilities and Services



Start Date =	5/3/2001
Stop Date =	6/7/2012
Hours =	97,272
NASA GRC Sensor Hours =	338,177
SAMS Sensor Hours =	204,164
MAMS Sensor Hours =	134,013

SAMS & MAMS stream acceleration data 24x7



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Capabilities and Services

NASA GRC Acceleration Services:

NEAR REAL-TIME

- receive, process, and archive SAMS, MAMS, & JAXA data
- provide near real-time data displays

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OFF-LINE

- daily “roadmap” (summary) plots for environment monitoring
- provide post-experiment support (off-line analysis)

Capabilities and Services

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ONGOING

- maintain a web site with links to:
  - educational information
  - analysis results
  - archive of as-measured data (including JAXA data)

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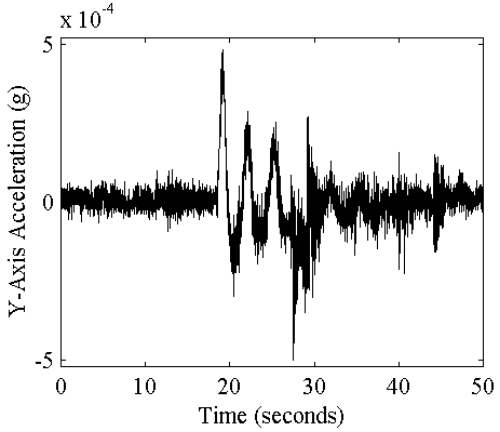
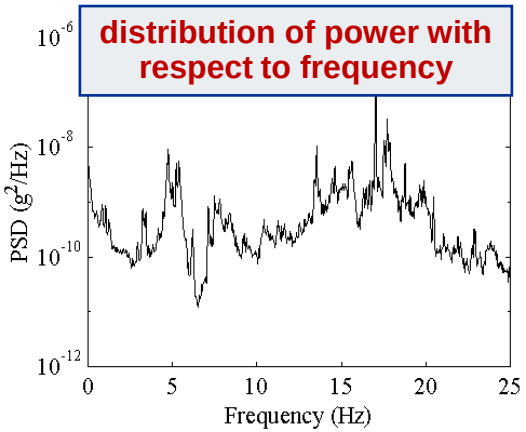
Capabilities and Services

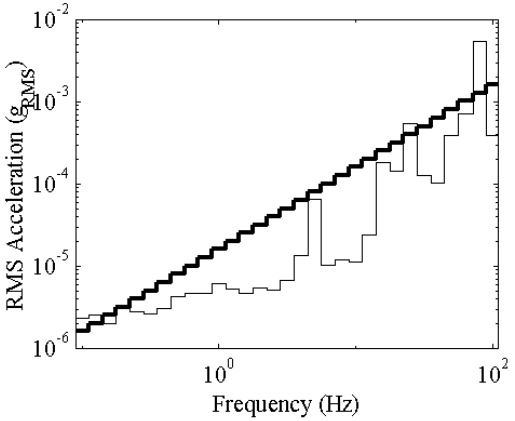
Acceleration vs. Time



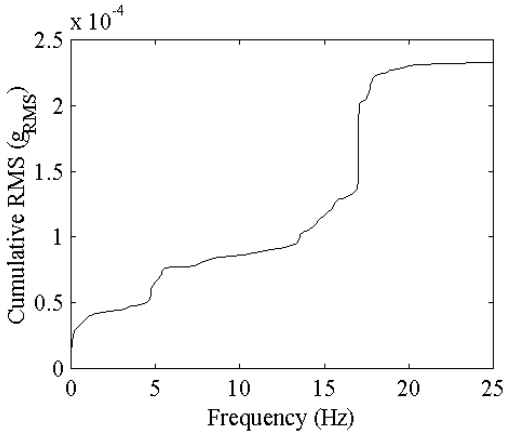
Power Spectral Density (PSD)

distribution of power with respect to frequency





RMS vs. 1/3 octave frequency bands



cumulative RMS vs. frequency

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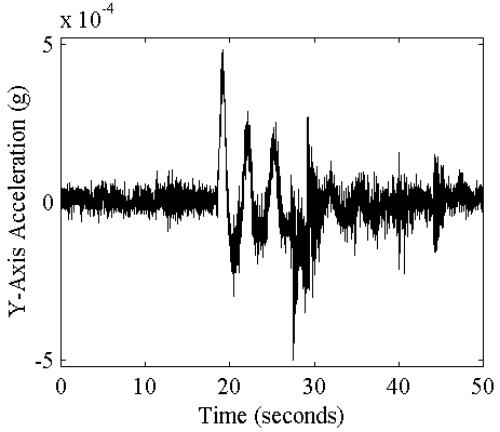
Capabilities and Services

Acceleration vs. Time



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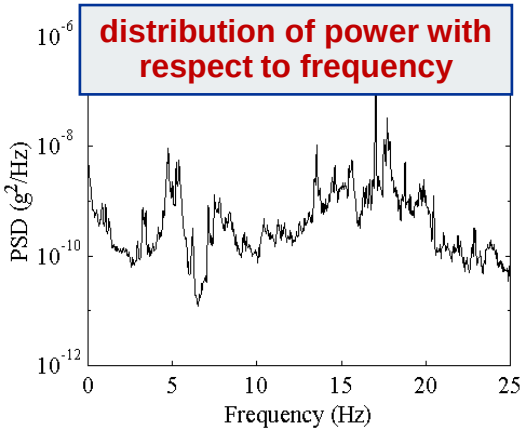
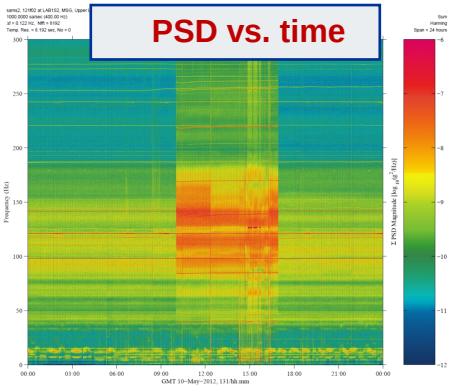
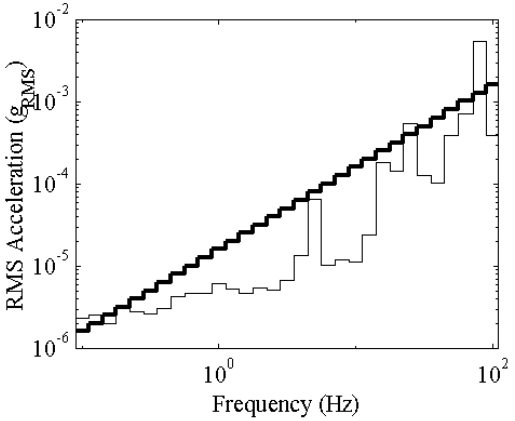


Spectrogram

PSD vs. time





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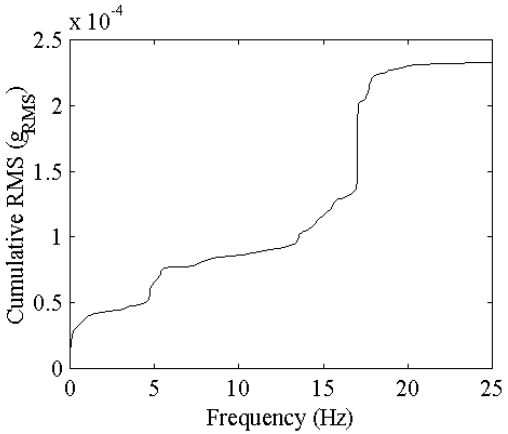

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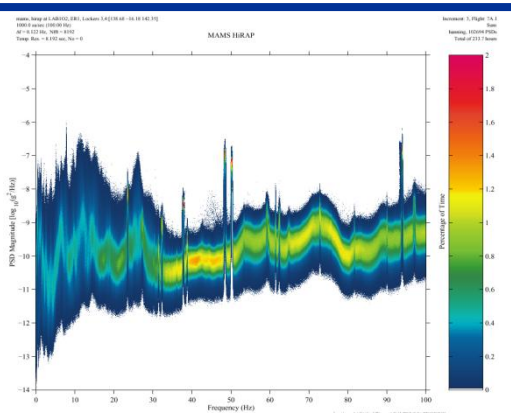

Principal Component Spectral Analysis (PCSA)

%time vs. PSD

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Science Support/Customers

NASA's Physical Sciences Research Program conducts fundamental & applied research with experiments in:

Fluid Physics

Combustion Science

Materials Science

Fundamental Physics

Complex Fluids

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Complex Fluids

SAMS/MAMS were designed to support these disciplines, and along with **PIMS** for analysis, these **NASA GRC-sponsored** projects also fill an ongoing role in support of:

Vehicle Loads and Dynamics Monitoring

Technology Developers

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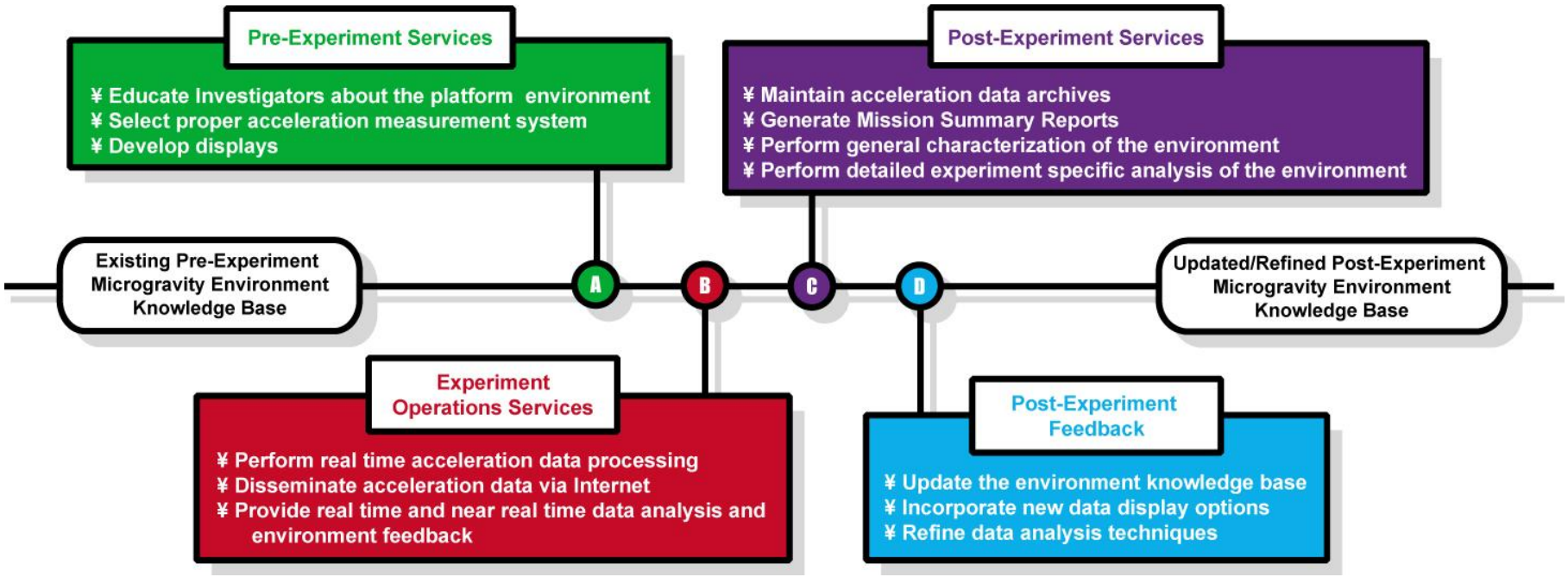
collaboration

Microgravity Community Feedback Model



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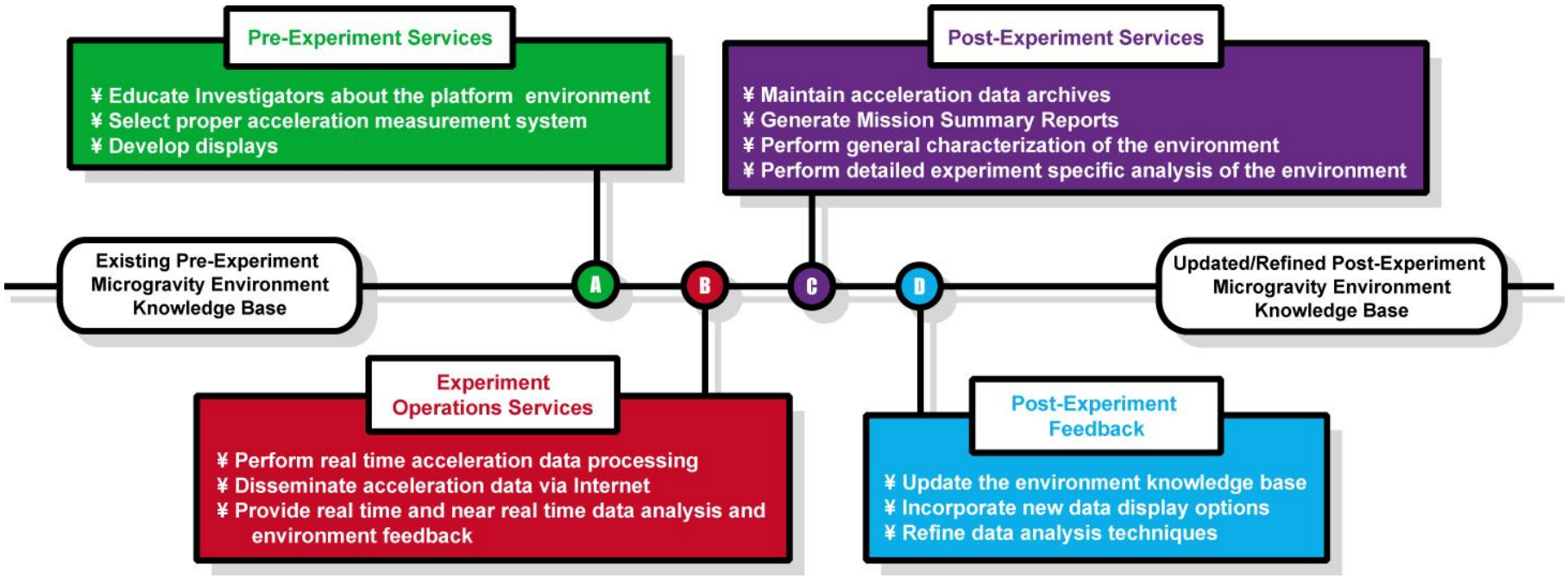
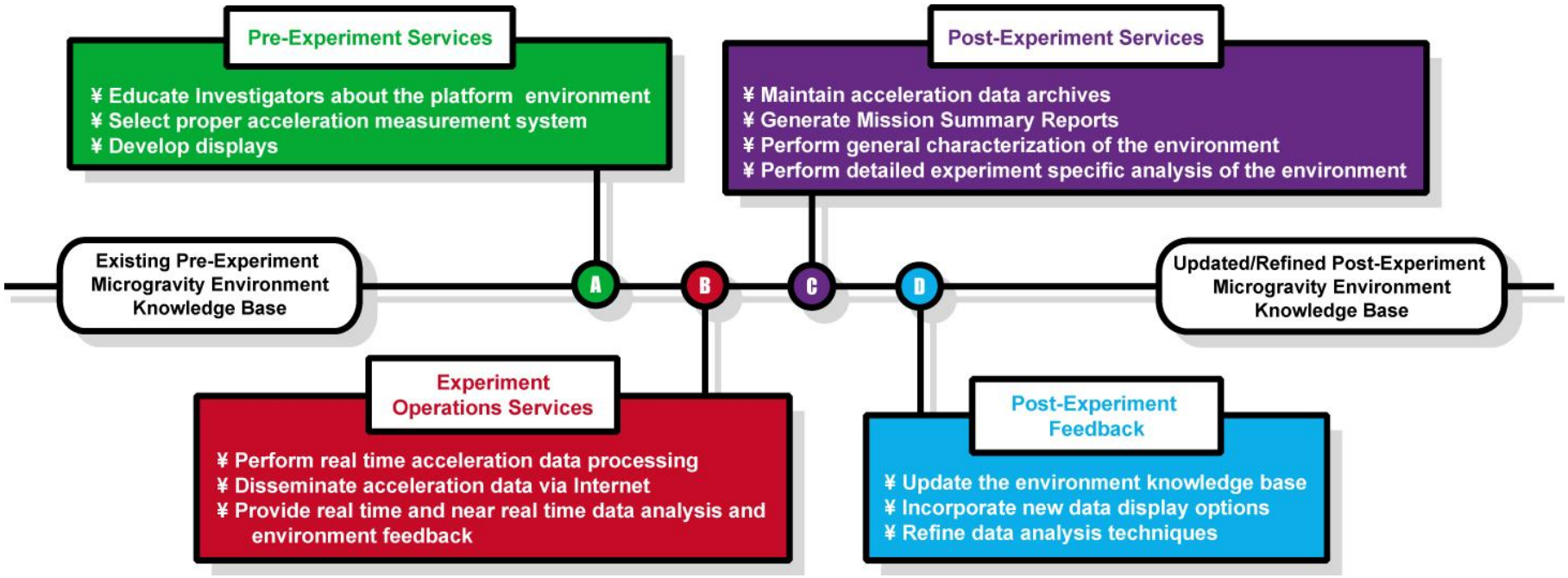


HIGHLIGHTS

- **Real-Time Displays:** http://pims.grc.nasa.gov/html/PIMS_ISS_plots.html
- **Acceleration Data Archive:** http://pims.grc.nasa.gov/ftp/pad
- **Characterization Handbook:** http://pims.grc.nasa.gov/handbook

Microgravity Community Feedback Model



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- **Characterization Handbook:** http://pims.grc.nasa.gov/handbook
- Peer-reviewed pub.: **comprehensive characterization** of ISS ug environment
- Plans to participate in **Open Government Initiative** on the web

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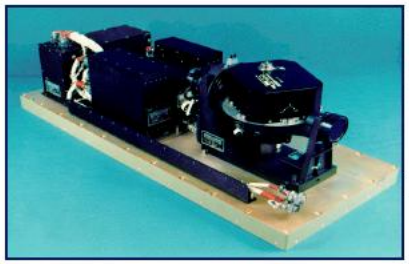
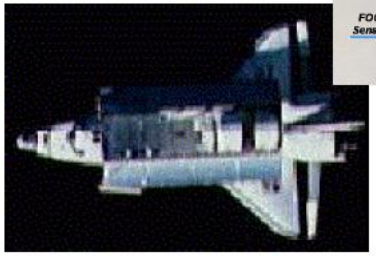
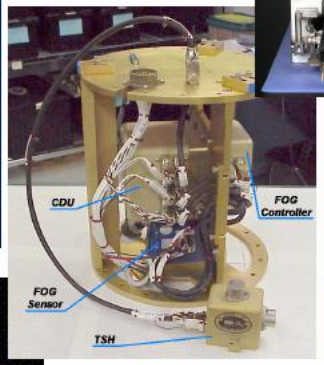
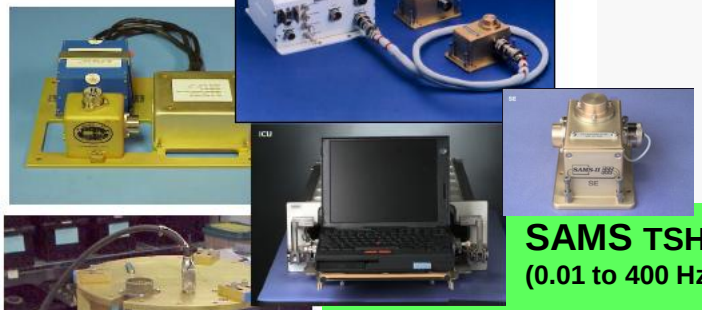
Timeline of NASA GRC System Deployment









SAMS TSH-ES (Compact Ethernet Standalone)
(0.01 to 400 Hz) Station Vibratory

SAMS RTS (Ethernet Distributed)
(0.01 to 400 Hz) Station Vibratory

MAMS HiRAP
(0.01 to 100 Hz) Station Vibratory

MAMS OSS
(DC to 1 Hz) Station Quasi-Steady

RRS (0.1 arc/s)
1 sounding rocket, 1 shuttle

TSH-FF (0.01 to 200 Hz)
3 sounding rocket, 2 shuttle

OARE (DC to 1Hz) - 12 shuttle flights

7 SAMS Units (0.01 to 100 Hz)
21 Shuttle/MIR Flights

SAMS Project Initiated

1986 1991 1994 1997 2000 2003 2006 2009 2012 2015 2018

YEAR

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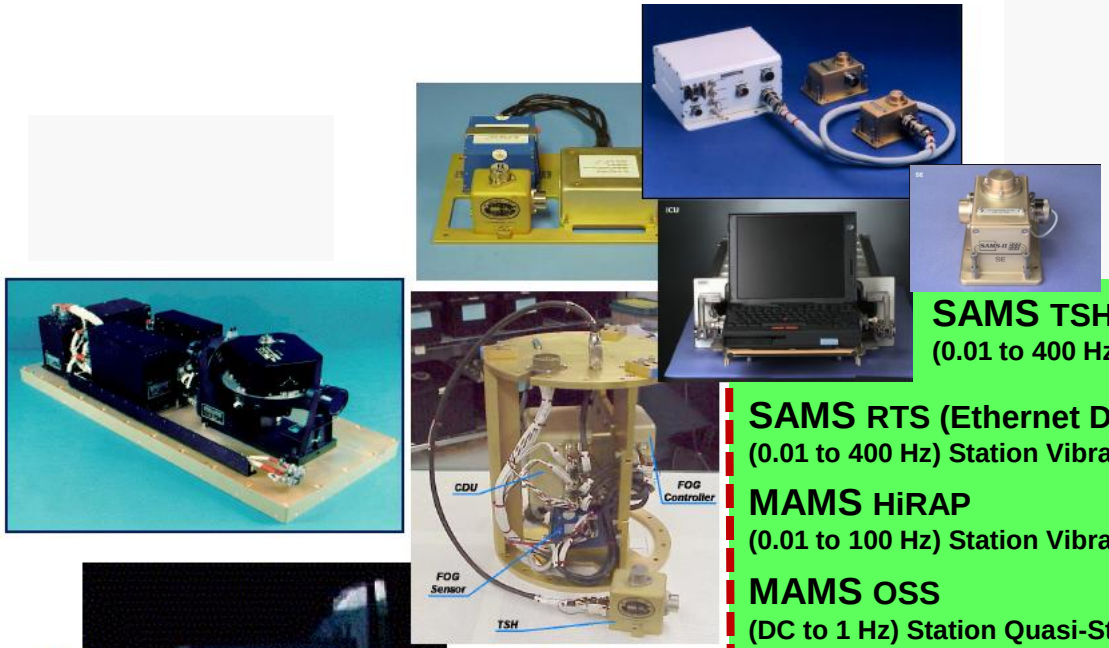
Timeline of NASA GRC System Deployment



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SAMS Project Initiated

on ISS from 2001 through...2028

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YEAR

Location of NASA GRC ISS Sensor Deployment

Collectively, SAMS & MAMS Sensors Have Been Mounted in 21 Unique Locations

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system	coord_name	location_name	r_orient	p_orient	y_orient	x_location	y_location	z_location
MAMS	**hirap**	**LAB1O2, ER1, Lockers 3,4**	**180**	**0**	**0**	**138.68**	**-16.18**	**142.35**
MAMS	**ossraw**	**LAB1O2, ER1, Lockers 3,4**	**90**	**0**	**0**	**135.28**	**-10.68**	**132.12**
SAMS	**121f02**	**LAB1S2, MSG, Upper Left Seat Track**	**0**	**0**	**90**	**161.95**	**40.39**	**157.64**
SAMS	**121f03**	**LAB1O1, ER2, Lower Z Panel**	**0**	**30**	**-90**	**191.54**	**-40.54**	**135.25**
SAMS	**121f04**	**LAB1O2, ER1, Lower Z Panel**	**0**	**30**	**-90**	**149.54**	**-40.54**	**135.25**
SAMS	**121f05**	**JPM1F5, ER4, Drawer 2**	**-90**	**-90**	**0**	**466.8**	**-292.06**	**214.58**
SAMS	**121f08**	**COL1A1, ER3, Seat Track near D1**	**0**	**0**	**180**	**371.17**	**193.43**	**165.75**
SAMS	**es05**	**LAB1S3, CIR, Front Panel**	**180**	**0**	**90**	**116.81**	**40.39**	**192.76**
SAMS	**es06**	**LAB1S4, FIR,**	**0**	**180**	**0**	**69.31**	**40.39**	**196.41**
SAMS	es08	COL1F2, MSG, Ceiling Plate Y1-C3 Y2-D3	0	90	-90	475.71	235.22	160.27
SAMS	121f02	LAB1P3, CEVIS, Frame	0	0	-90	118.45	-38.36	170.57
SAMS	121f02	LAB1O2, ER1, Drawer 1	-90	0	-90	128.73	-23.53	144.15
SAMS	121f02	JPM1F3, TCQ, Lower Panel	180	-45	0	455.55	-227.69	229.07
SAMS	121f02	COL1D3, Forward Foot of FWED	90	-45	-90	395.08	287.99	232.22
SAMS	121f05	LAB1O1, ER2, Upper Z Panel	90	0	90	185.17	38.55	149.93
SAMS	121f08	LAB1S3, MSG, Ceiling Plate A2-A3	-90	90	0	115.21	53.41	160.98
SAMS	121f08	LAB1S3, MSG, Ceiling Plate D3-D2	90	90	0	87.99	55.19	160.98
SAMS	121f08	COL1A1, ER3, B2 Panel	0	180	0	374.17	166.19	157.03
SAMS	121f08	COL1O1, FSL, ODM Seat Track	0	90	0	434.37	183.25	147.01
SAMS	121f08	COL1D3, Seat Track near A3	0	-90	0	378.11	246.46	234.96
SAMS	es08	COL1F2, MSG, Ceiling Plage Y1-B1 Y2-A1	0	90	90	475.63	204.91	159.95

Location of NASA GRC ISS Sensor Deployment

Collectively, SAMS & MAMS Sensors Have Been Mounted in 21 Unique Locations

Current

system	coord_name	location_name	r_orient	p_orient	y_orient	x_location	y_location	z_location
MAMS	**hirap**	**LAB1O2, ER1, Lockers 3,4**	**180**	**0**	**0**	**138.68**	**-16.18**	**142.35**
MAMS	**ossraw**	**LAB1O2, ER1, Lockers 3,4**	**90**	**0**	**0**	**135.28**	**-10.68**	**132.12**
SAMS	**121f02**	**LAB1S2, MSG, Upper Left Seat Track**	**0**	**0**	**90**	**161.95**	**40.39**	**157.64**
SAMS	**121f03**	**LAB1O1, ER2, Lower Z Panel**	**0**	**30**	**-90**	**191.54**	**-40.54**	**135.25**
SAMS	**121f04**	**LAB1O2, ER1, Lower Z Panel**	**0**	**30**	**-90**	**149.54**	**-40.54**	**135.25**
SAMS	**121f05**	**JPM1F5, ER4, Drawer 2**	**-90**	**-90**	**0**	**466.8**	**-292.06**	**214.58**
SAMS	**121f08**	**COL1A1, ER3, Seat Track near D1**	**0**	**0**	**180**	**371.17**	**193.43**	**165.75**
SAMS	**es05**	**LAB1S3, CIR, Front Panel**	**180**	**0**	**90**	**116.81**	**40.39**	**192.76**
SAMS	**es06**	**LAB1S4, FIR,**	**0**	**180**	**0**	**69.31**	**40.39**	**196.41**

Previous

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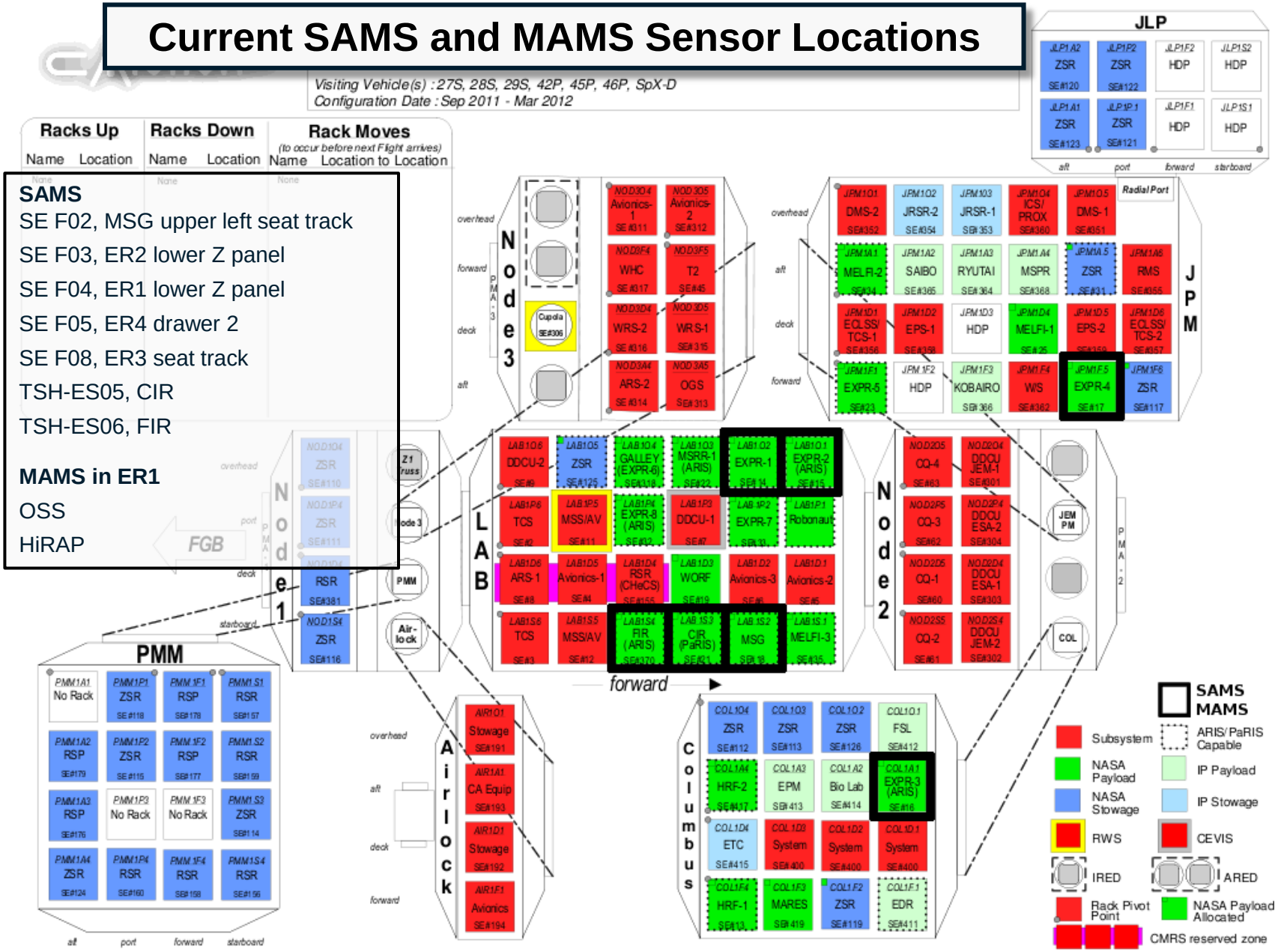
SAMS	es08	COL1F2, MSG, Ceiling Plate Y1-C3 Y2-D3	0	90	-90	475.71	235.22	160.27
SAMS	121f02	LAB1P3, CEVIS, Frame	0	0	-90	118.45	-38.36	170.57
SAMS	121f02	LAB1O2, ER1, Drawer 1	-90	0	-90	128.73	-23.53	144.15
SAMS	121f02	JPM1F3, TCQ, Lower Panel	180	-45	0	455.55	-227.69	229.07
SAMS	121f02	COL1D3, Forward Foot of FWED	90	-45	-90	395.08	287.99	232.22
SAMS	121f05	LAB1O1, ER2, Upper Z Panel	90	0	90	185.17	38.55	149.93
SAMS	121f08	LAB1S3, MSG, Ceiling Plate A2-A3	-90	90	0	115.21	53.41	160.98
SAMS	121f08	LAB1S3, MSG, Ceiling Plate D3-D2	90	90	0	87.99	55.19	160.98
SAMS	121f08	COL1A1, ER3, B2 Panel	0	180	0	374.17	166.19	157.03
SAMS	121f08	COL1O1, FSL, ODM Seat Track	0	90	0	434.37	183.25	147.01
SAMS	121f08	COL1D3, Seat Track near A3	0	-90	0	378.11	246.46	234.96
SAMS	es08	COL1F2, MSG, Ceiling Plage Y1-B1 Y2-A1	0	90	90	475.63	204.91	159.95

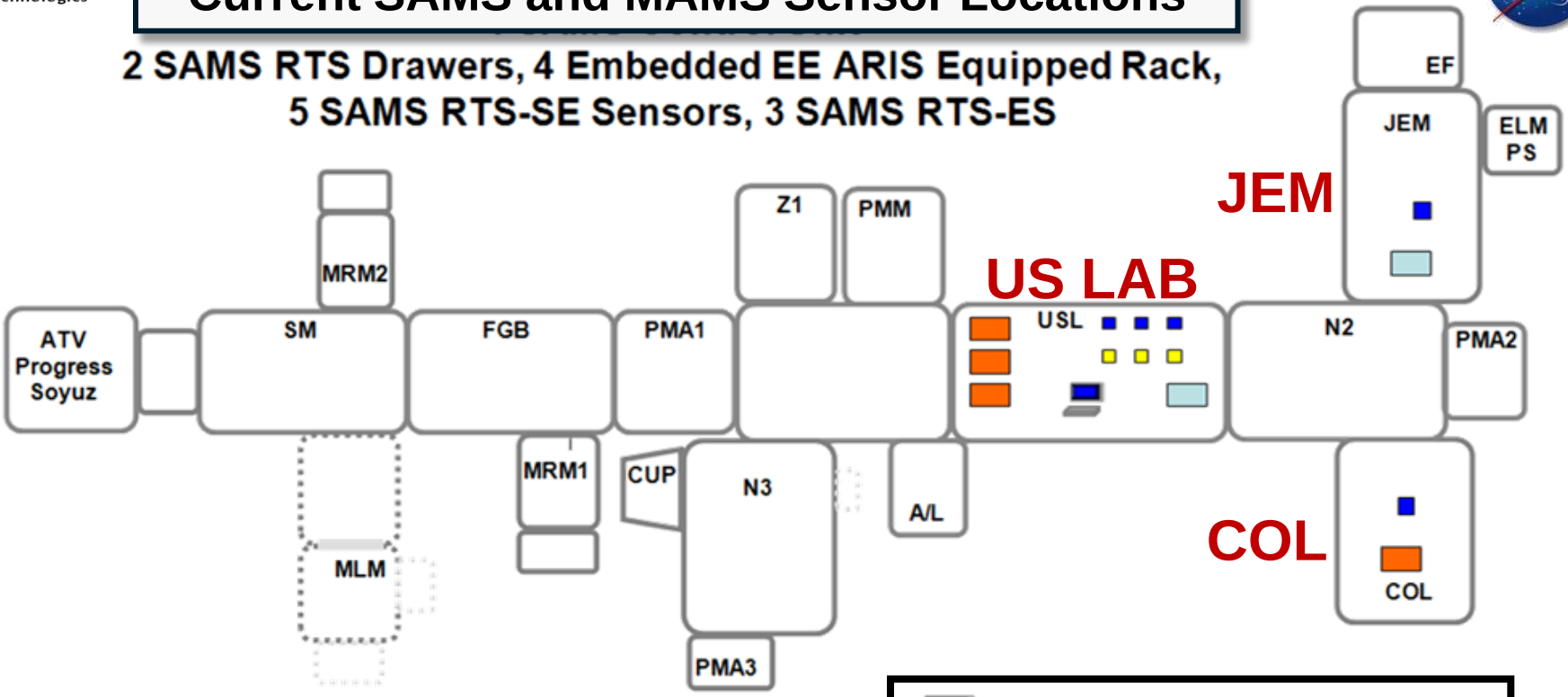
Current SAMS and MAMS Sensor Locations



ZIN Technologies

Current SAMS and MAMS Sensor Locations

2 SAMS RTS Drawers, 4 Embedded EE ARIS Equipped Rack, 5 SAMS RTS-SE Sensors, 3 SAMS RTS-ES



Outline

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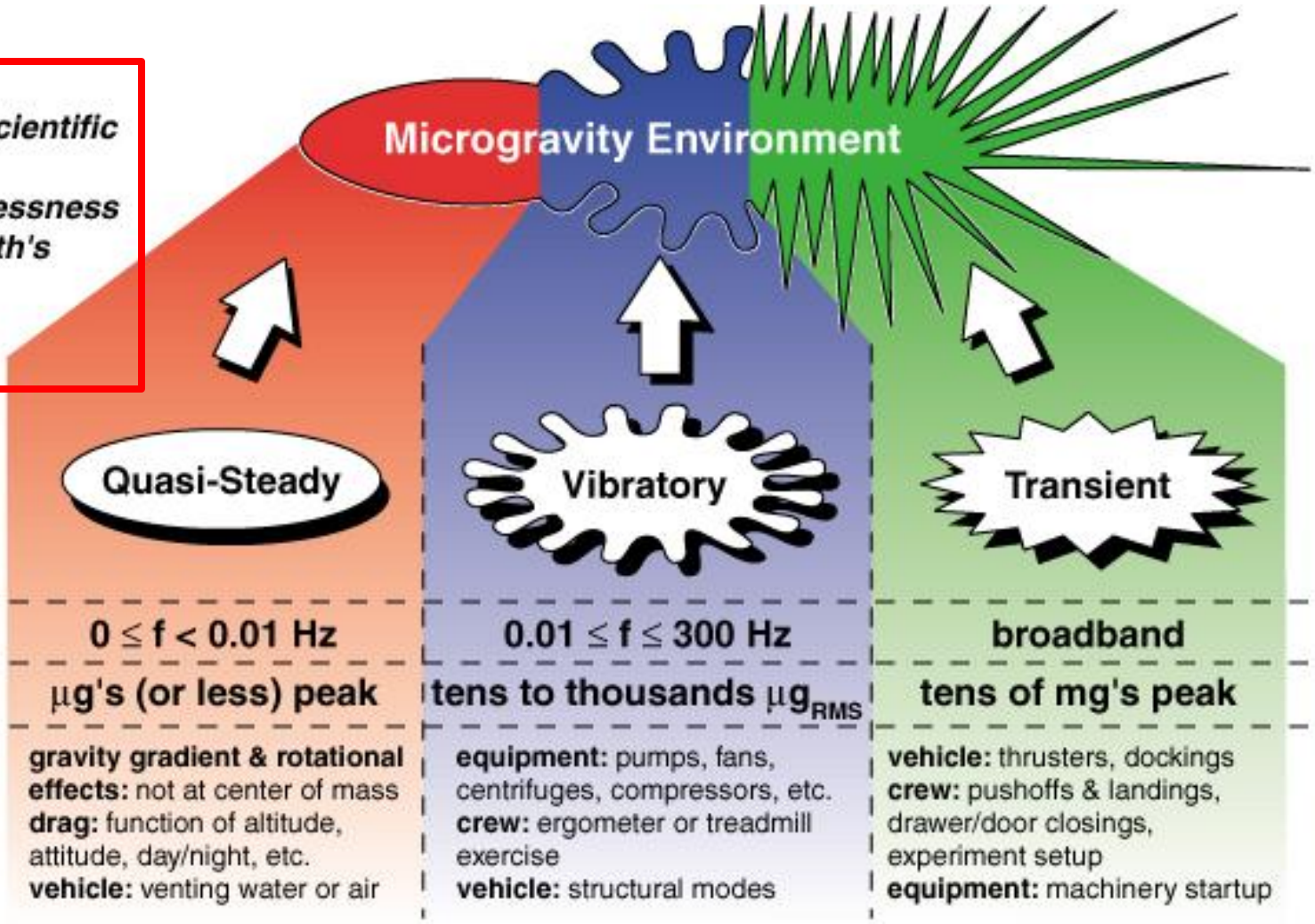
Overview of Microgravity Environment

Microgravity is:
- ***a general label for scientific investigations that exploit near-weightlessness***
- ***one-millionth of Earth's normal gravity***
- ***a reduced gravity environment***



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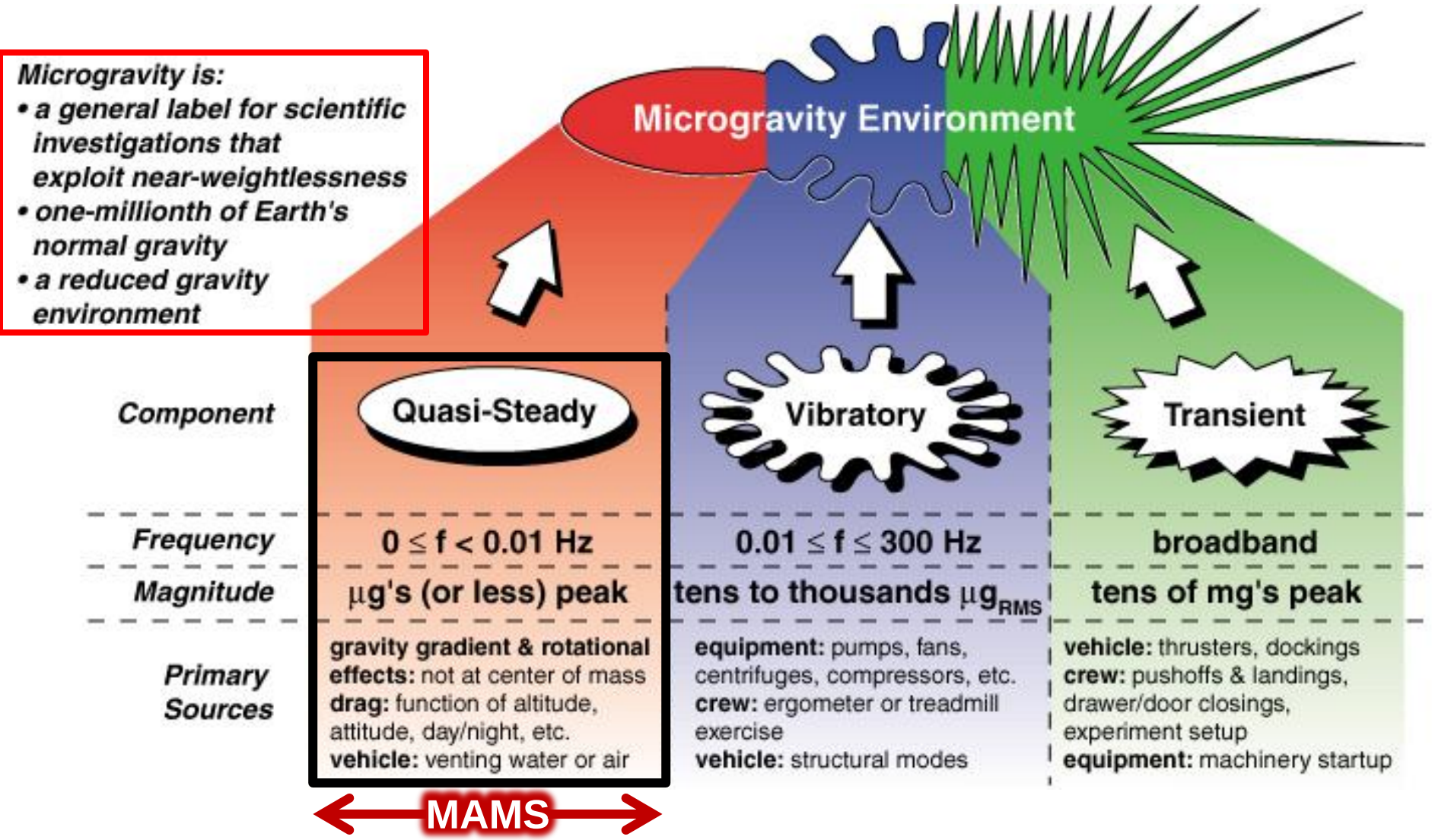

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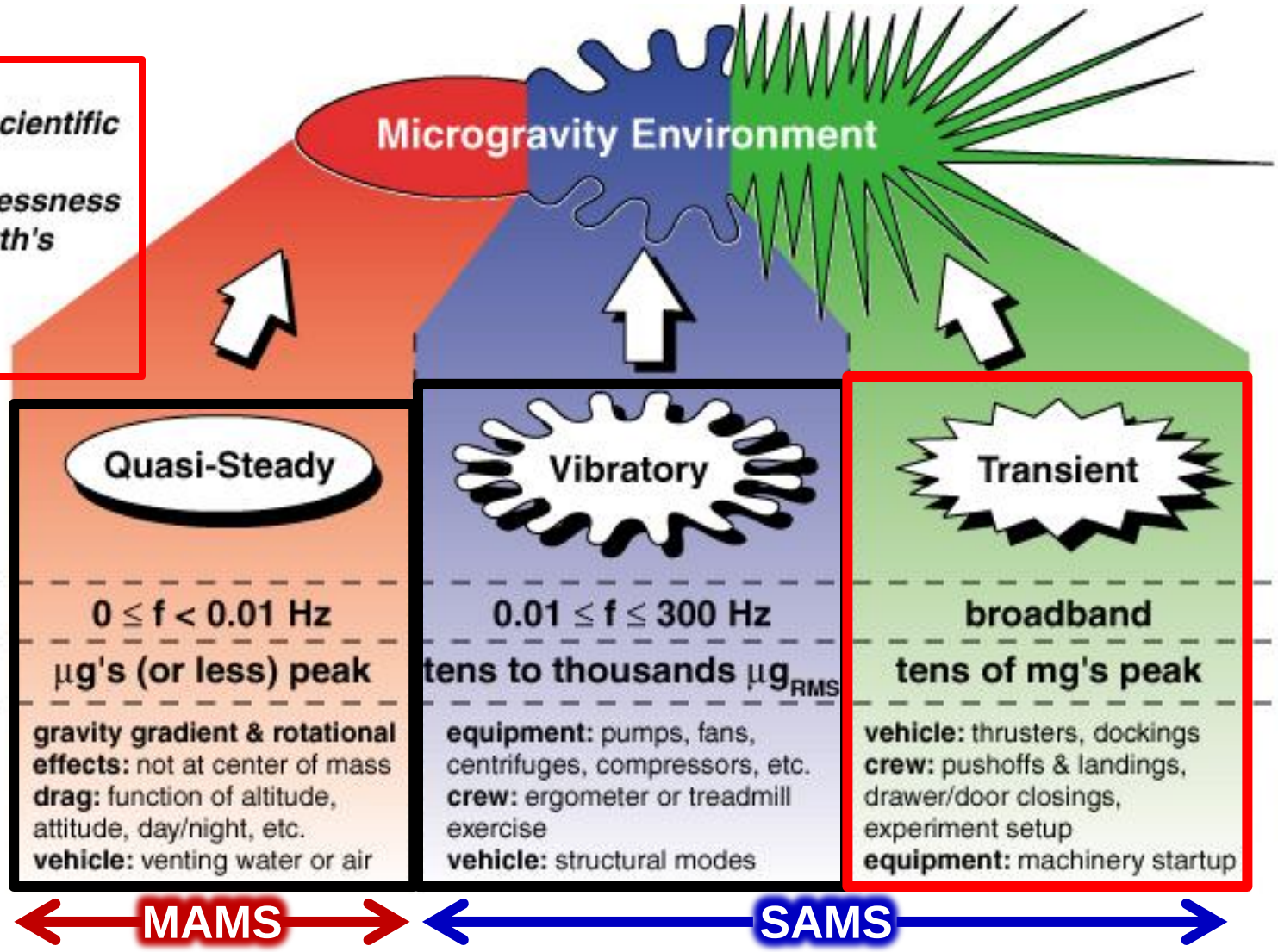
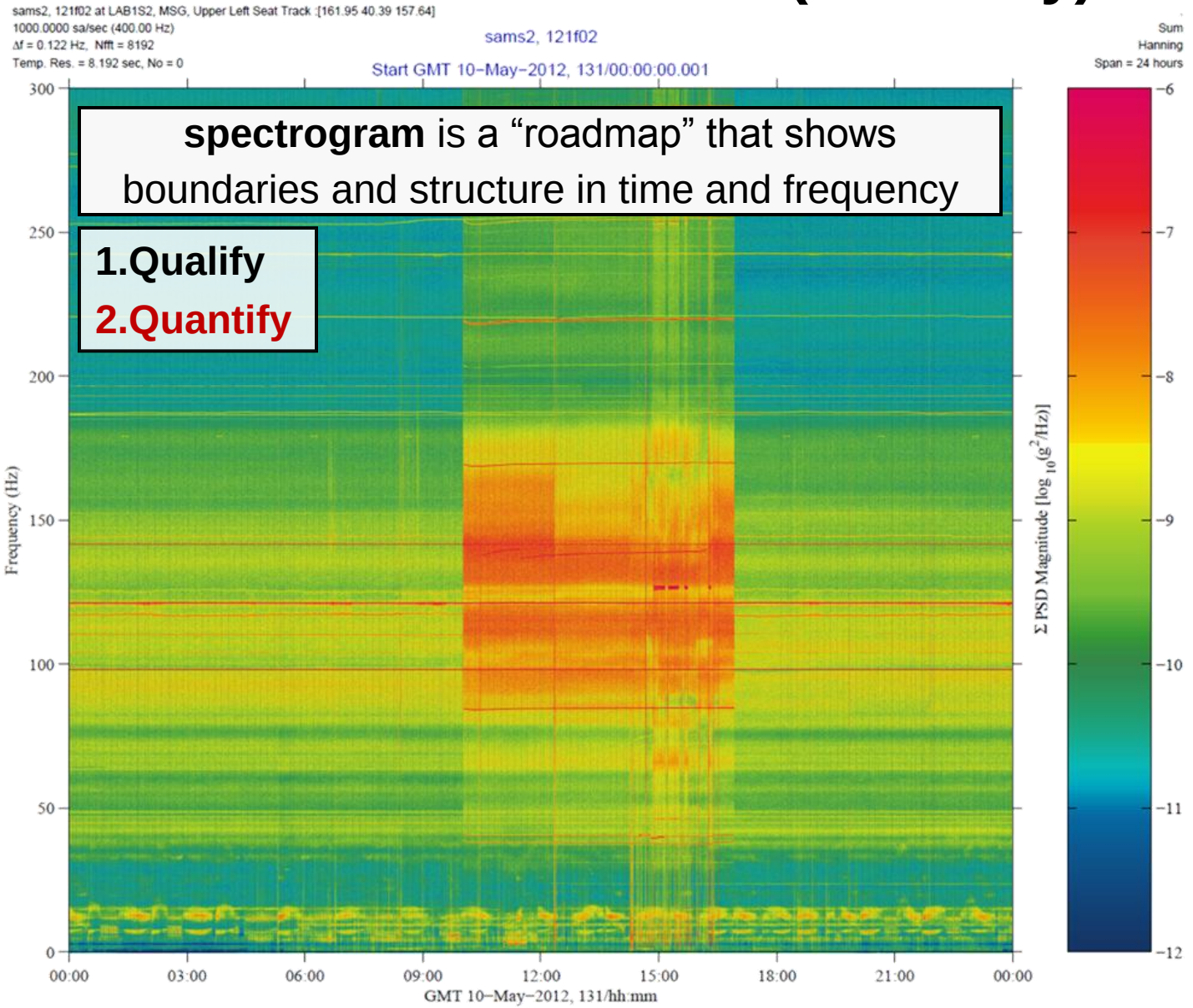


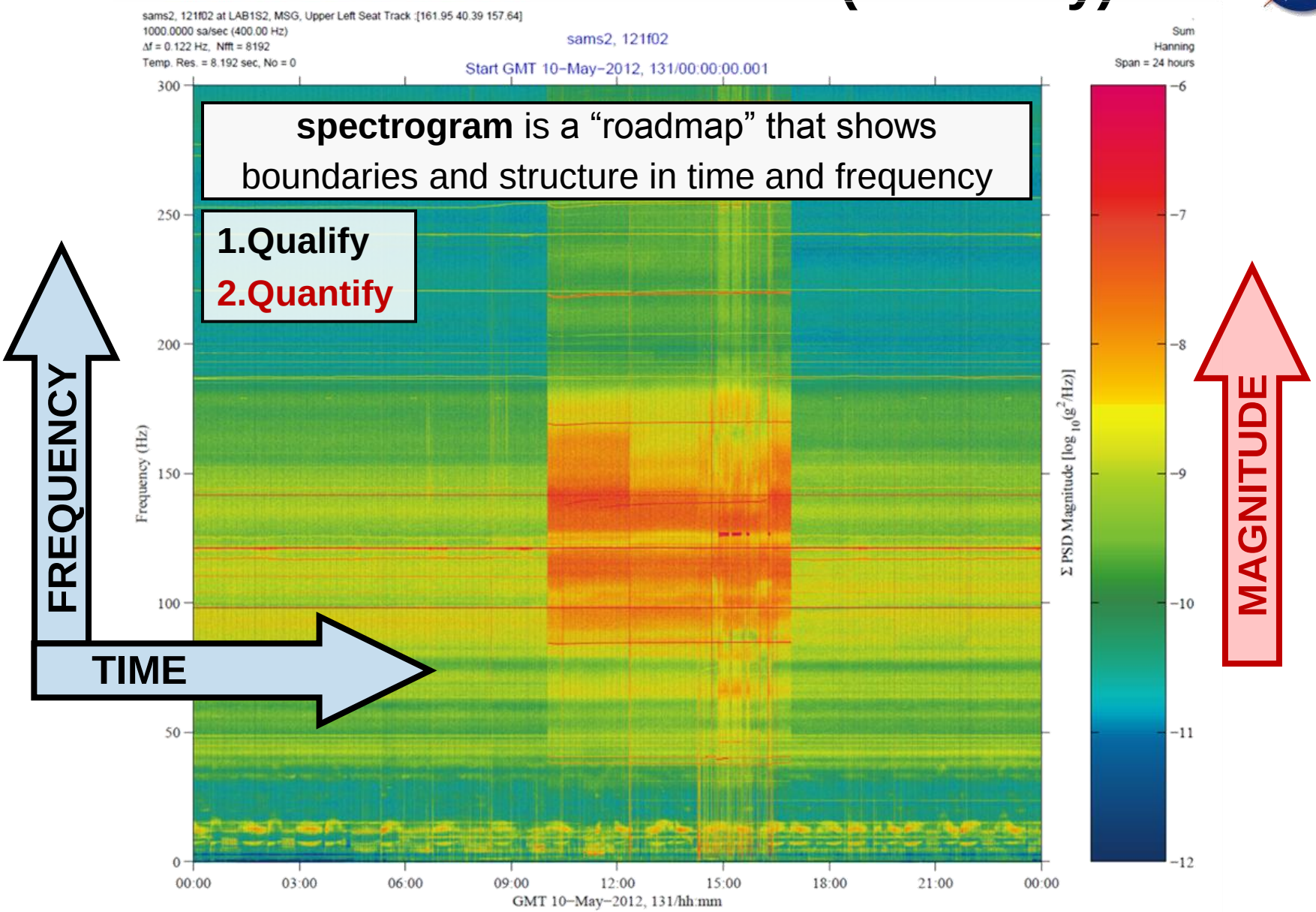
ZIN Technologies

Basic Characterization (vibratory)



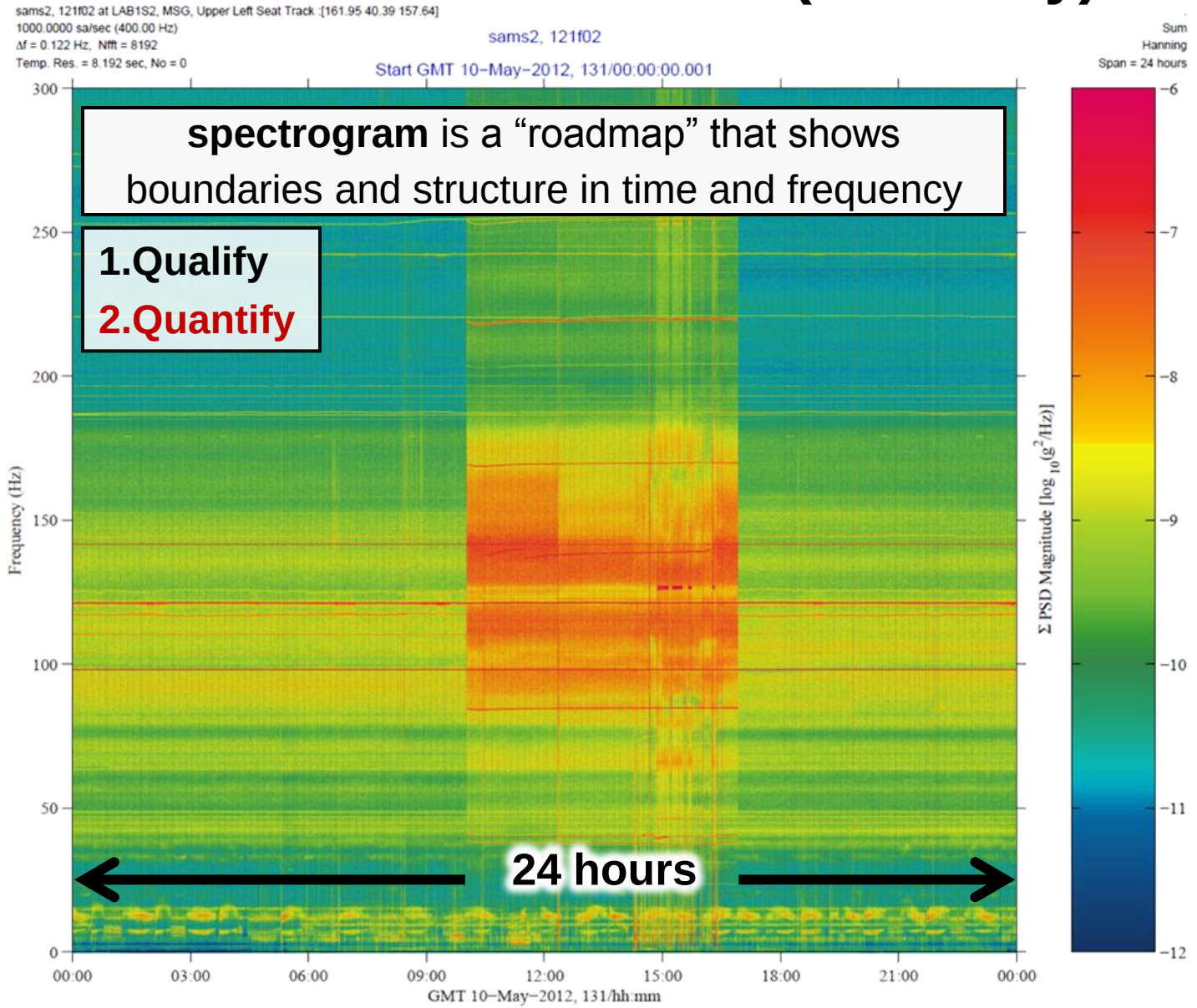
ZIN Technologies

Basic Characterization (vibratory)



ZIN Technologies

Basic Characterization (vibratory)



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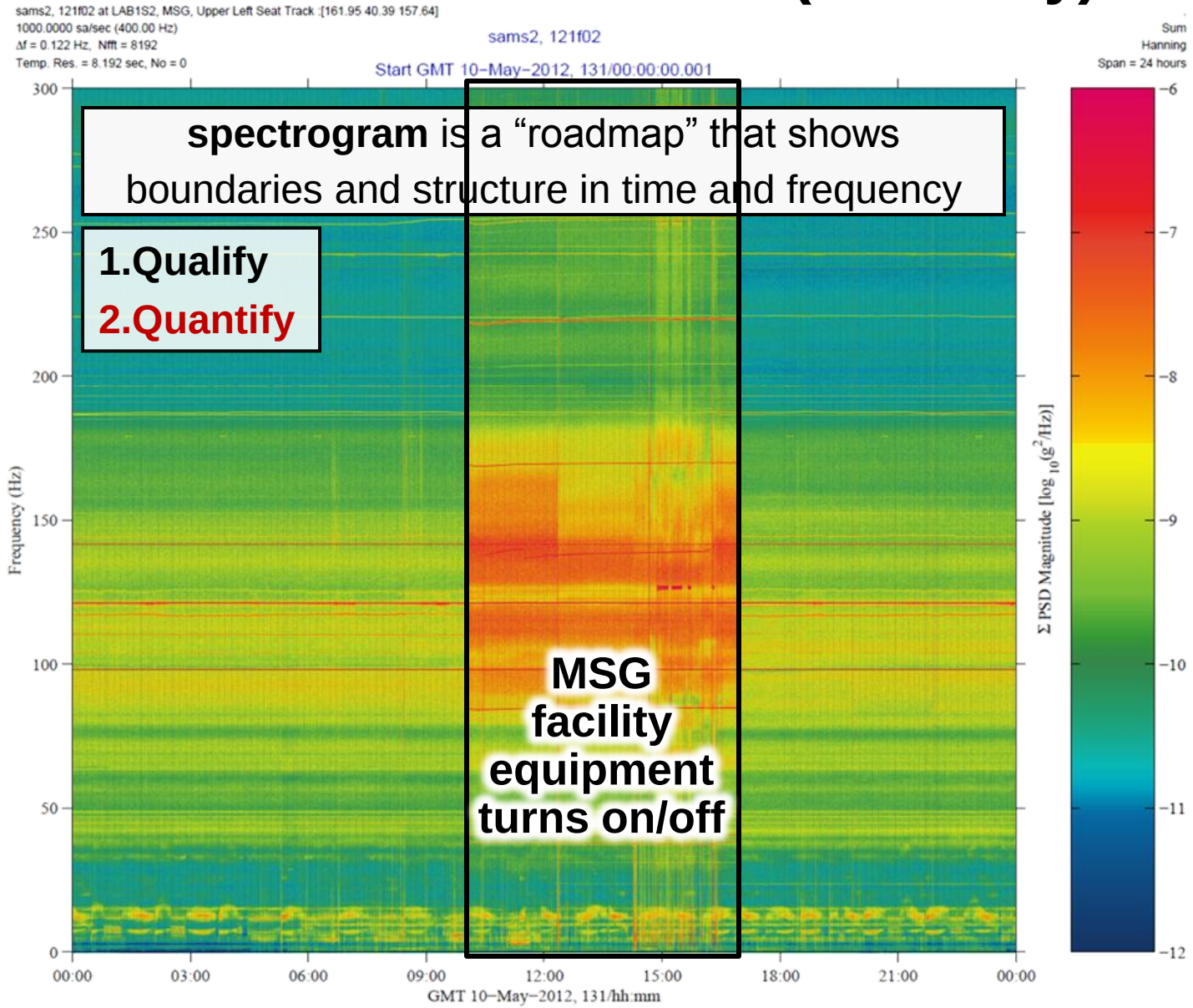
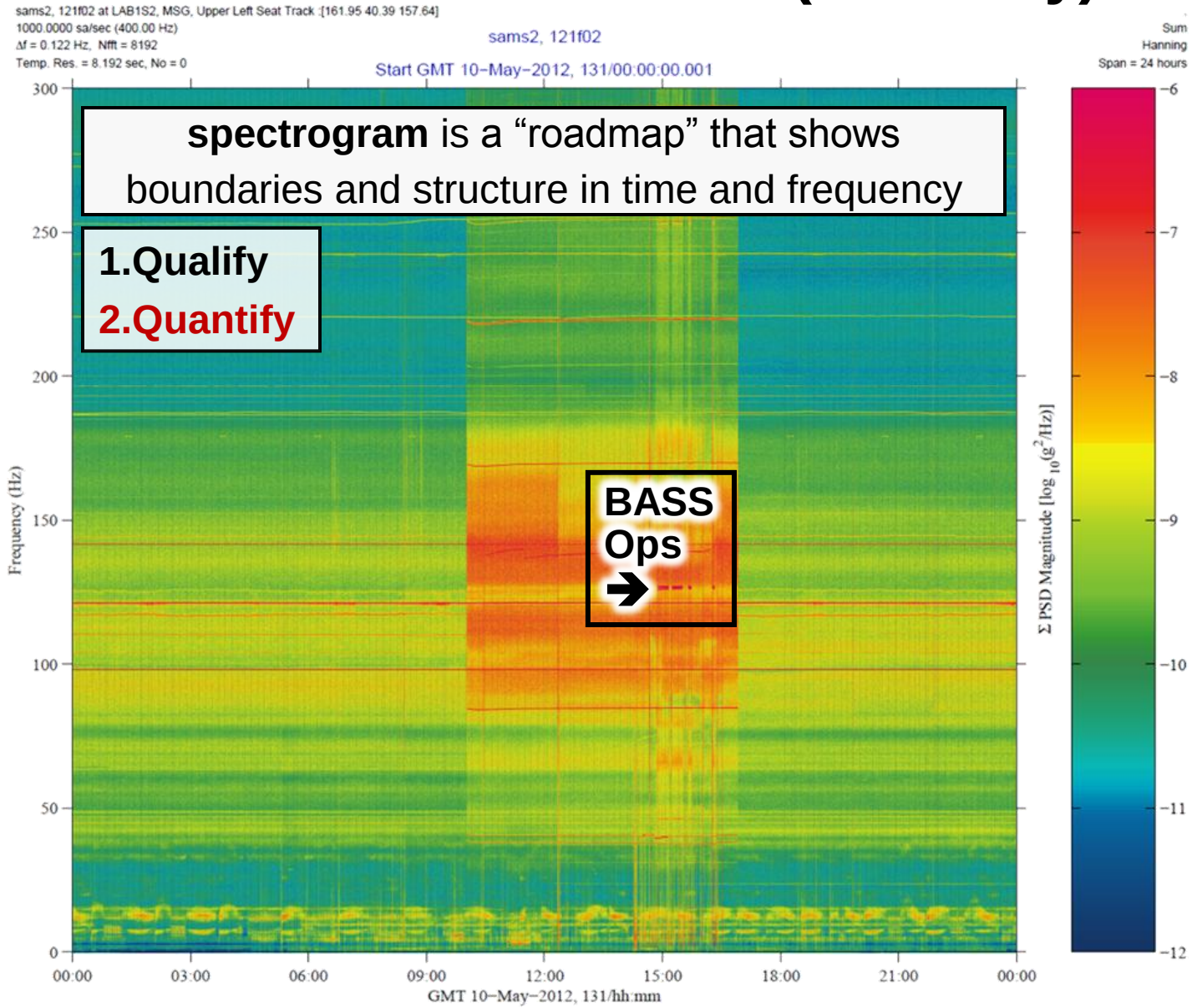
Basic Characterization (vibratory)



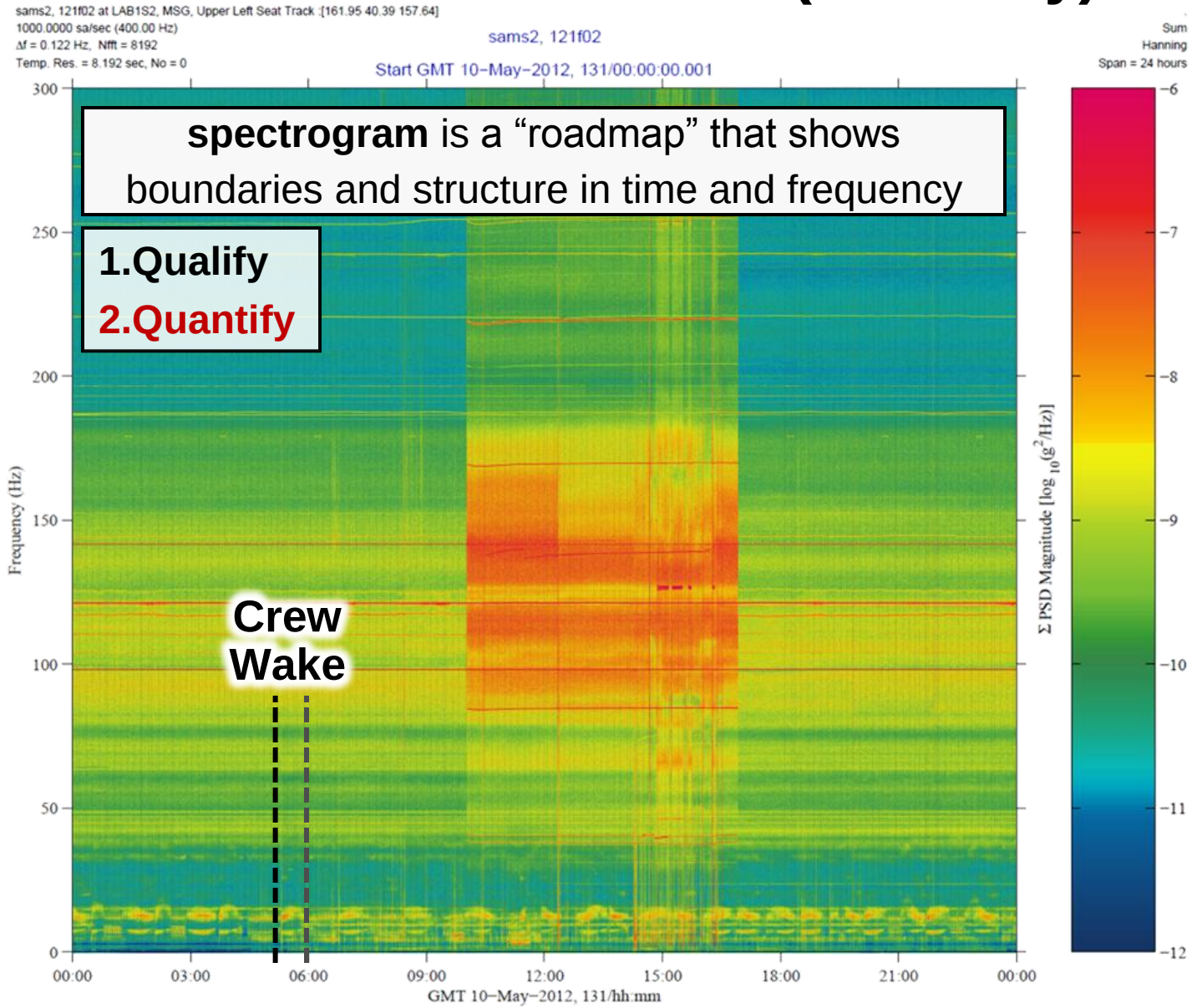
ZIN Technologies

Basic Characterization (vibratory)



ZIN Technologies

Basic Characterization (vibratory)



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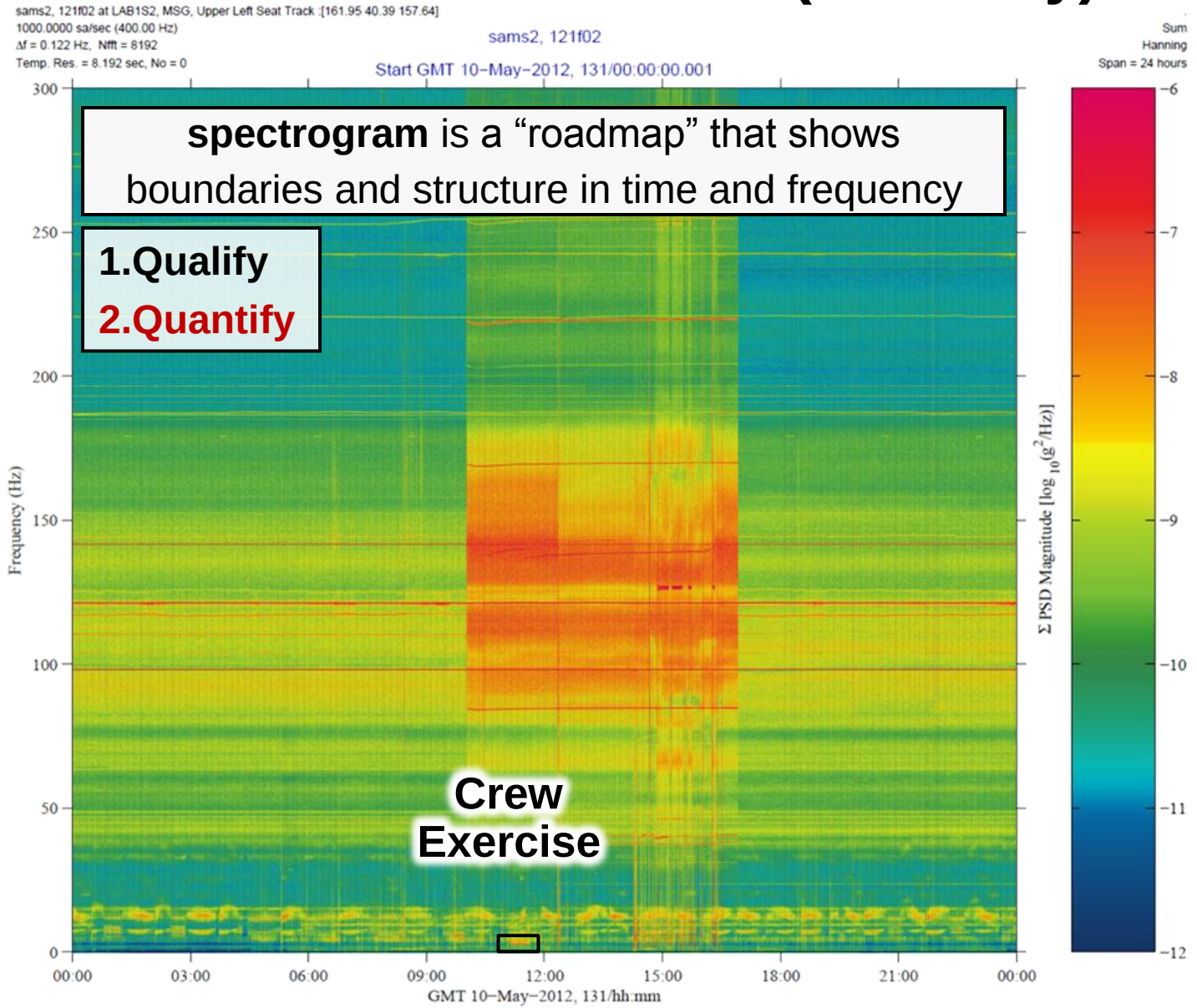
Basic Characterization (vibratory)



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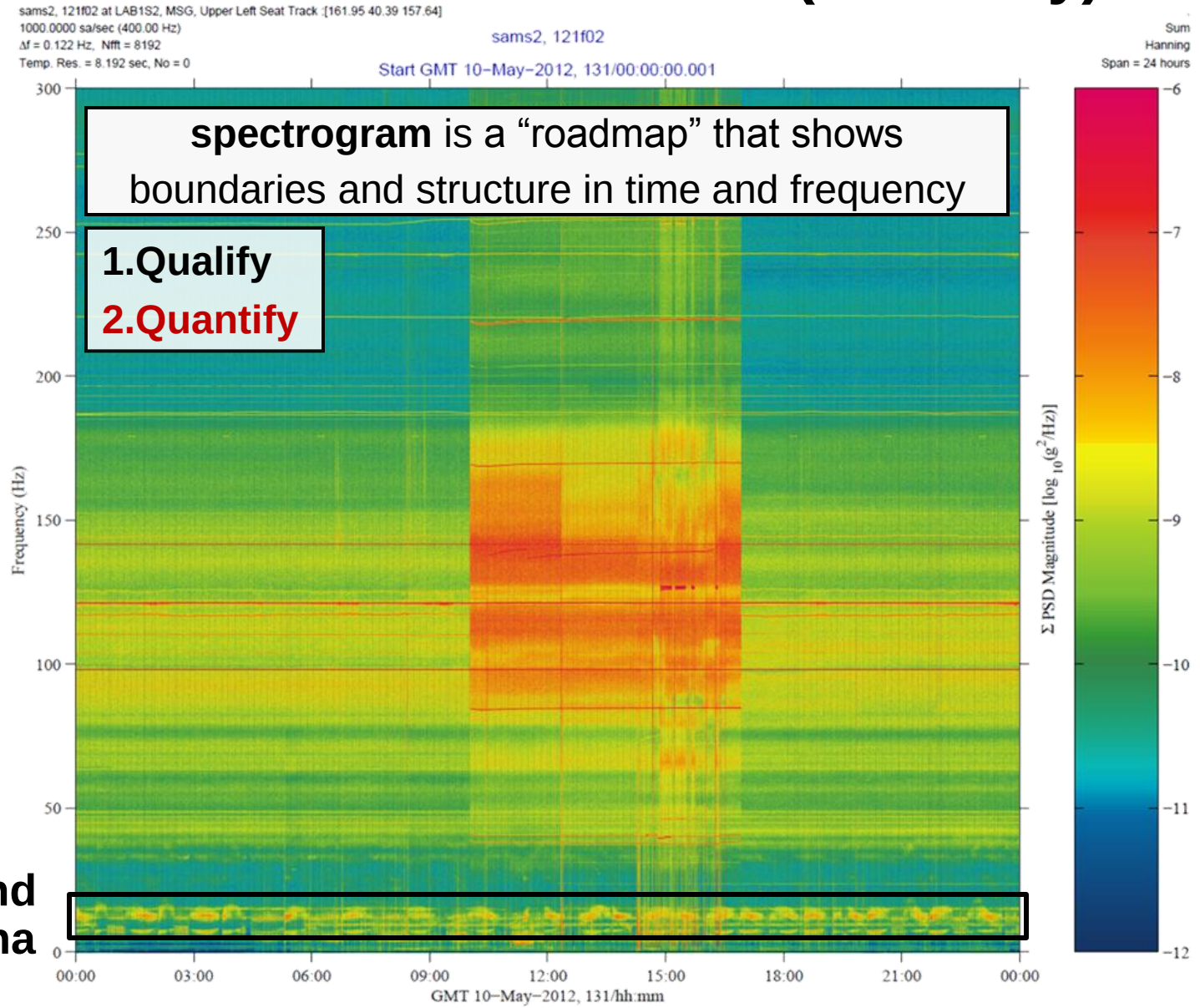
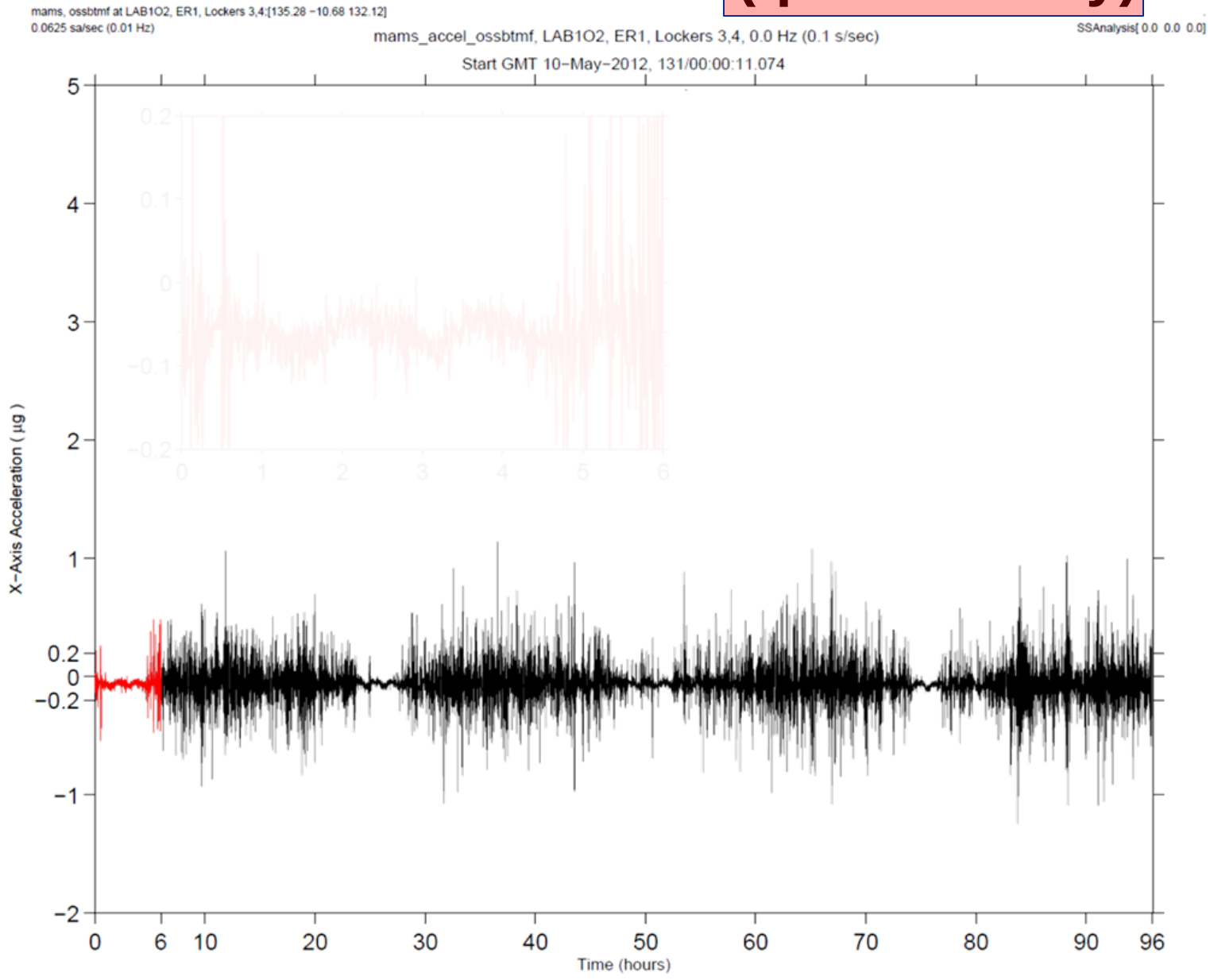


Ku-band Antenna

ZIN Technologies

Basic Characterization (quasi-steady)



ZIN Technologies

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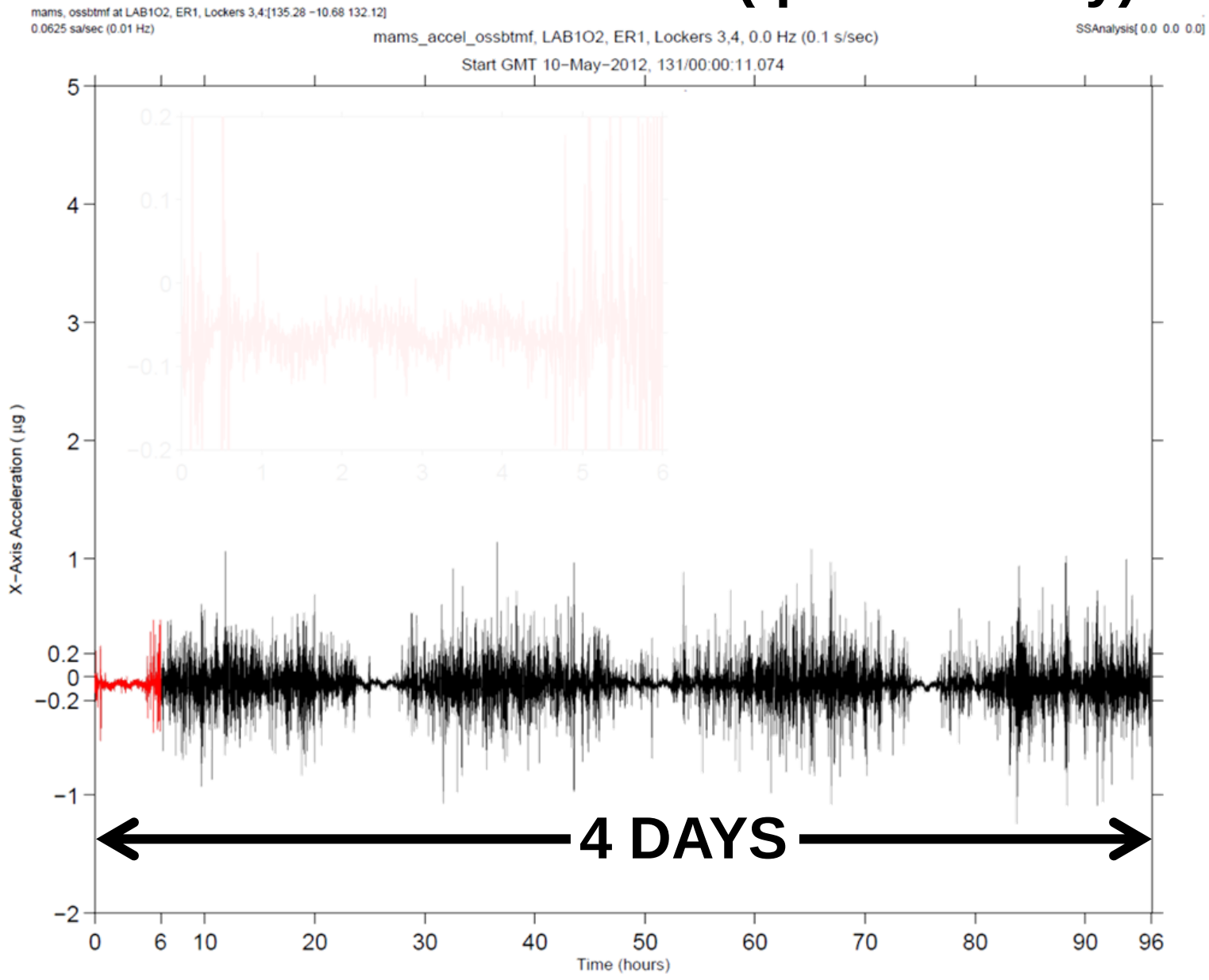

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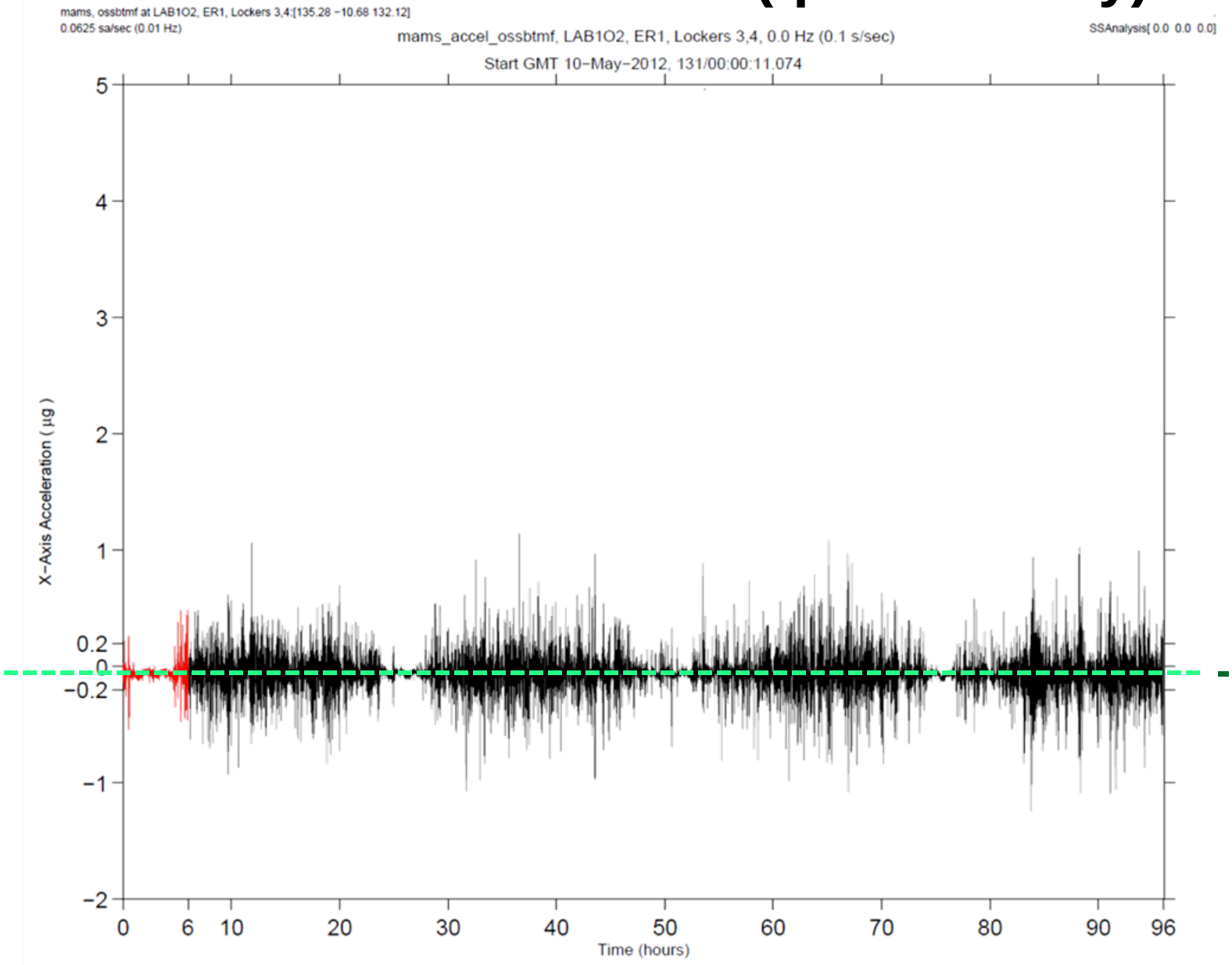

-60 ng

ZIN Technologies

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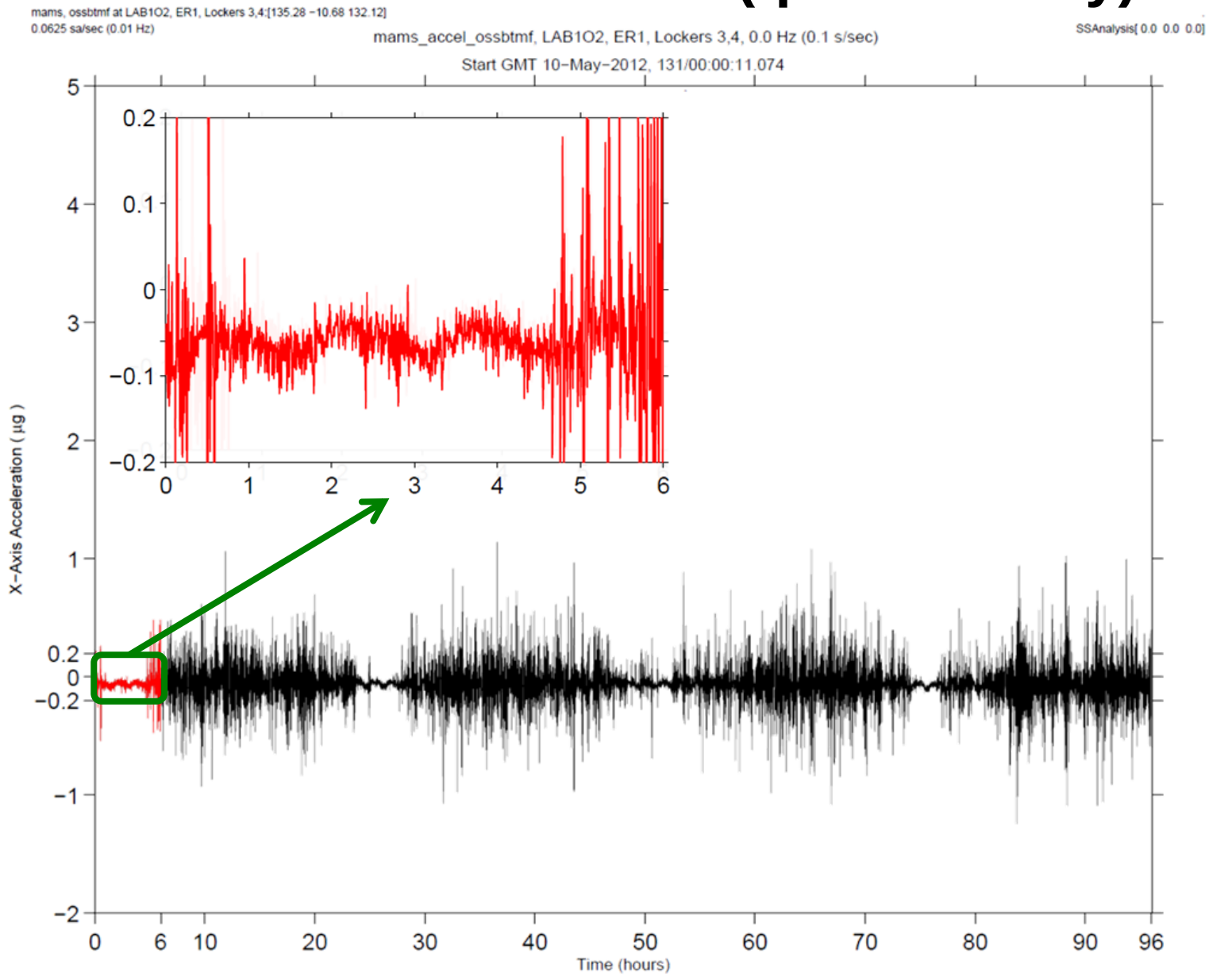

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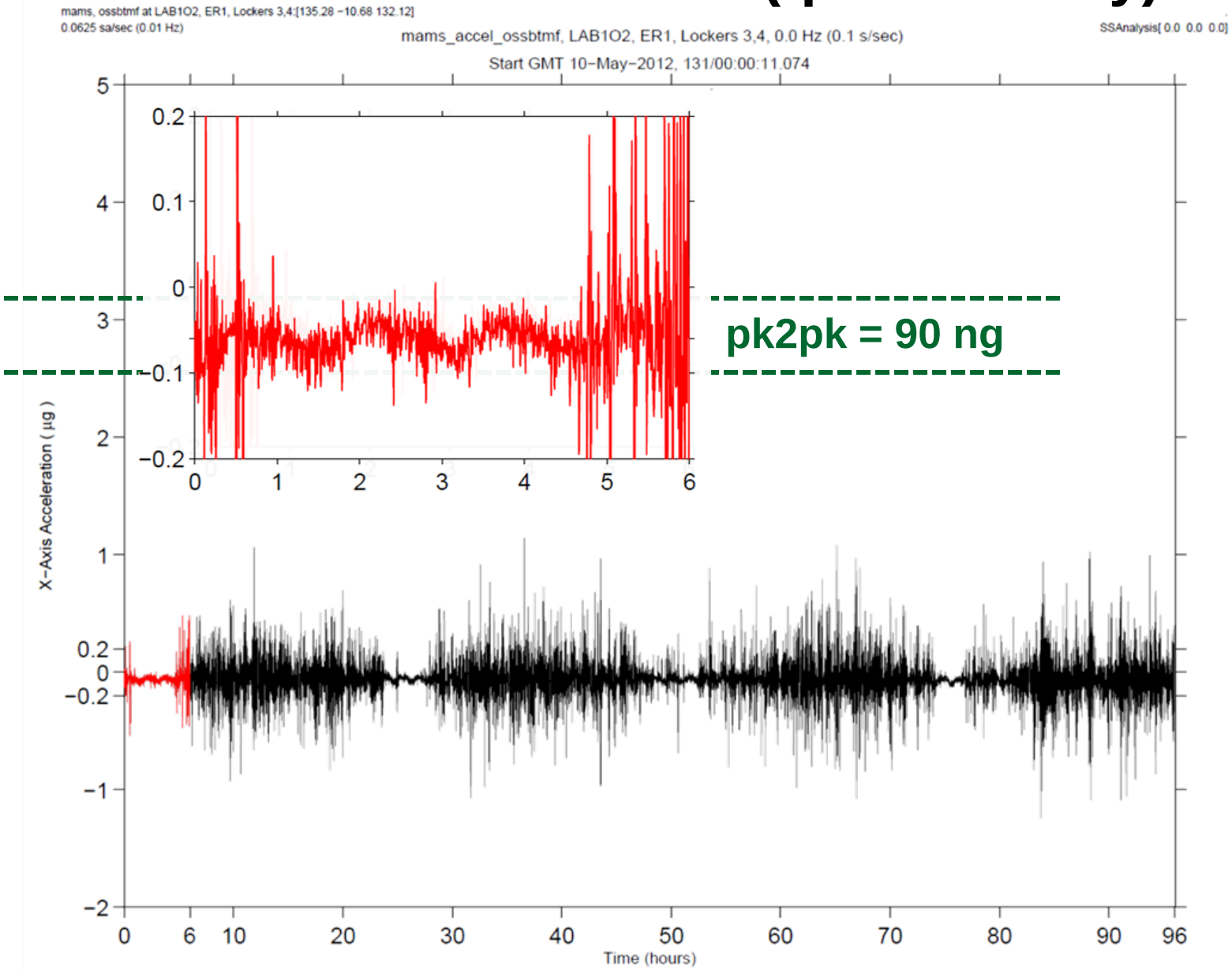

ZIN Technologies

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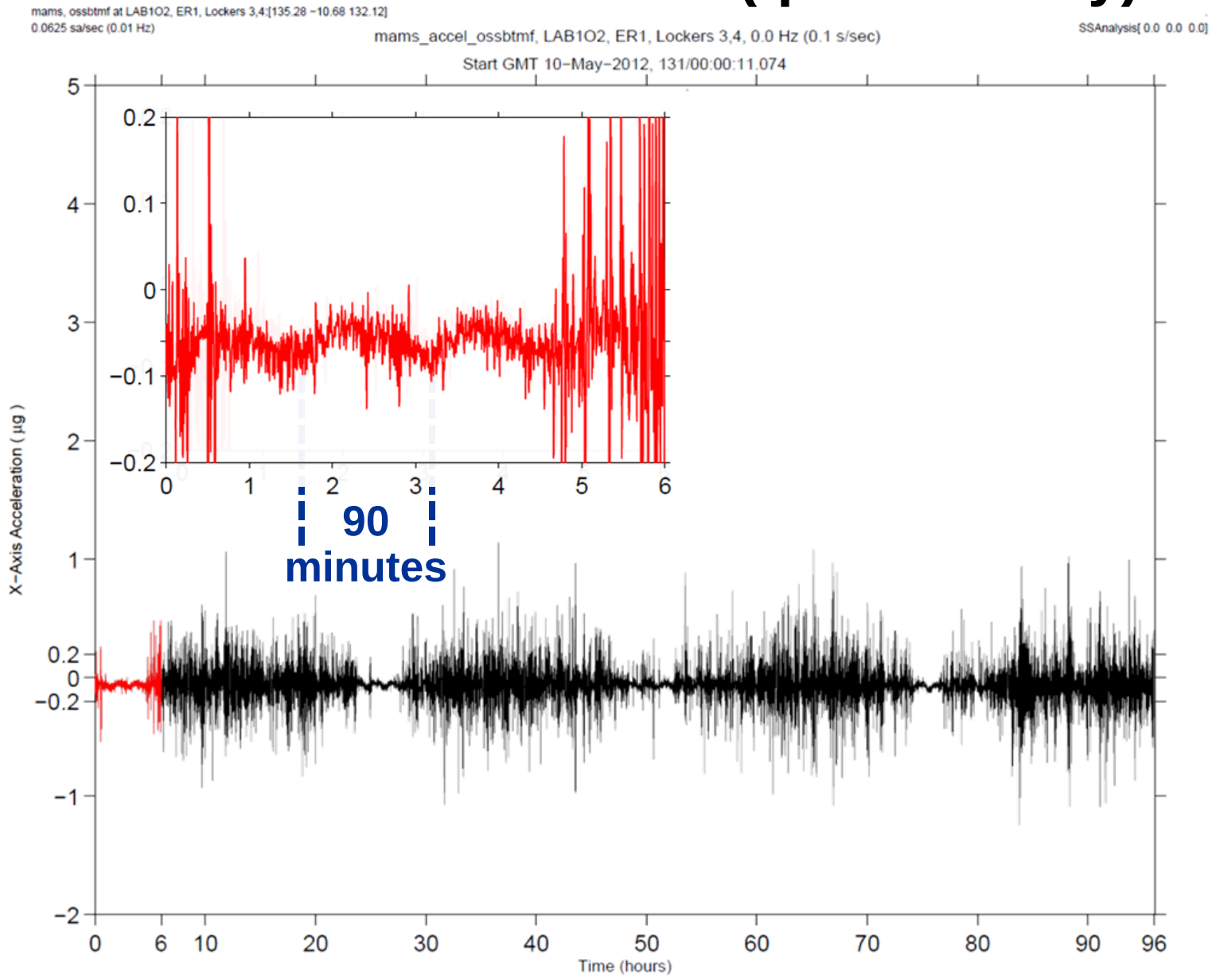

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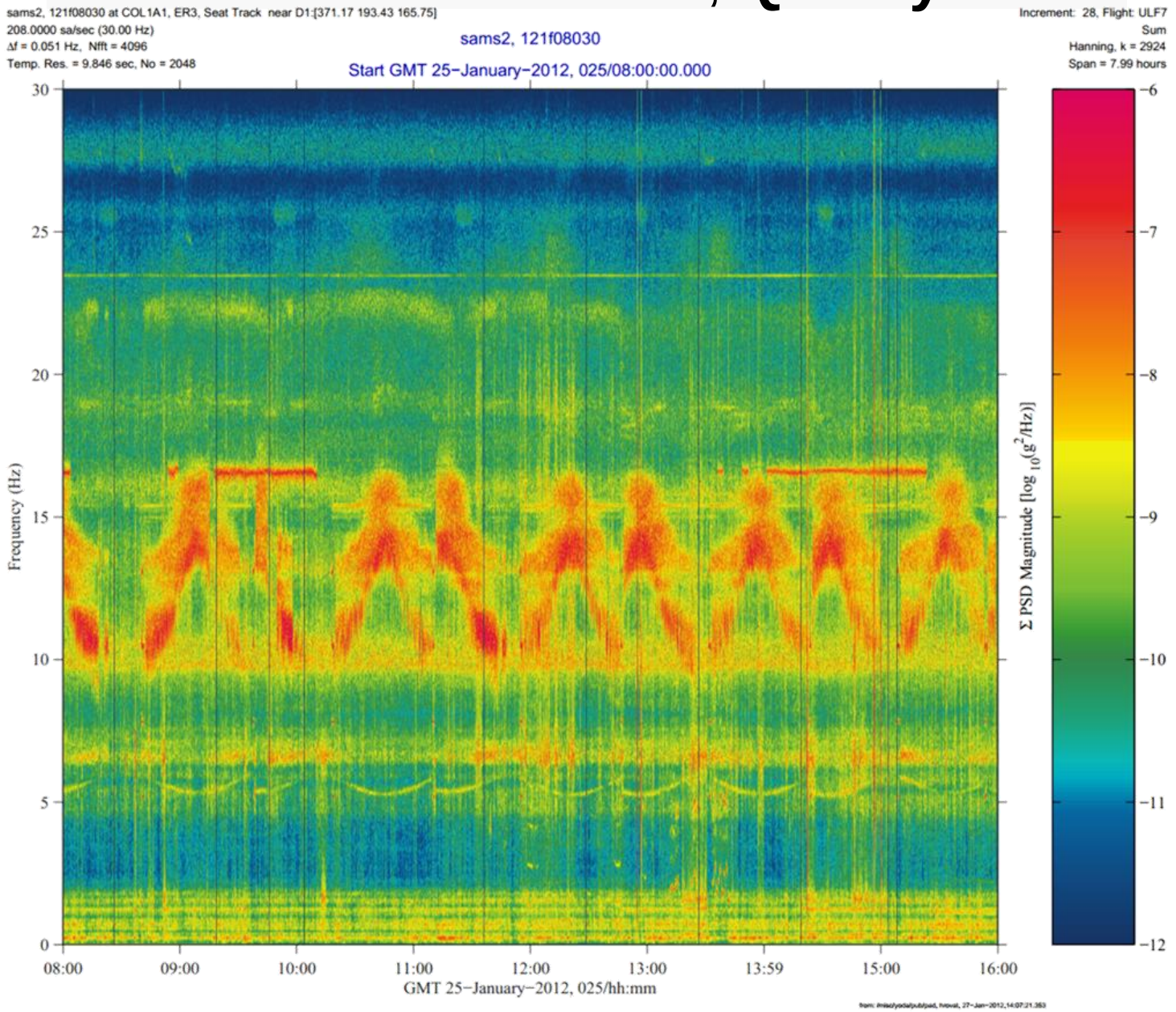
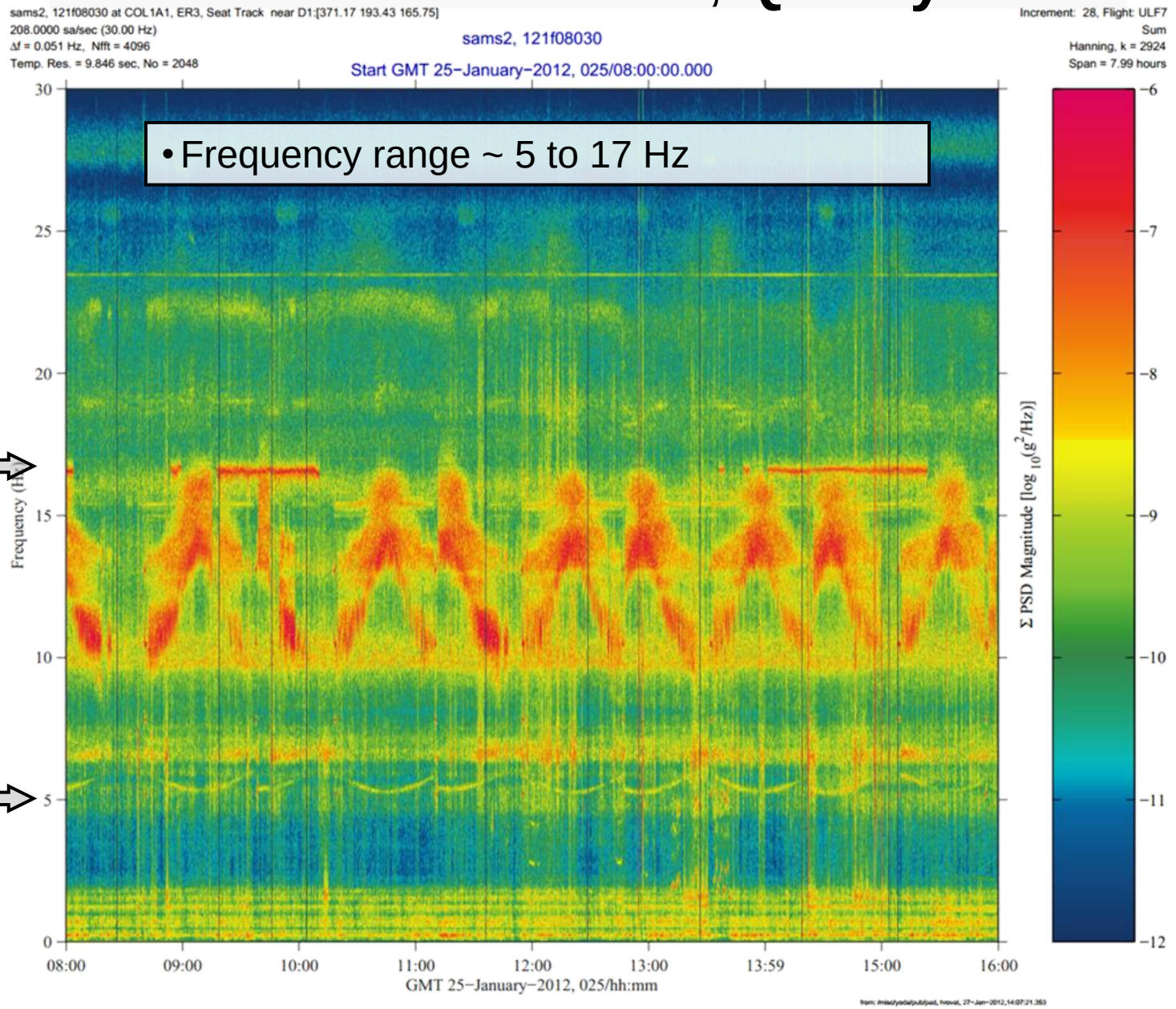
ZIN Technologies

Ku-Band Antenna, **Qualify**



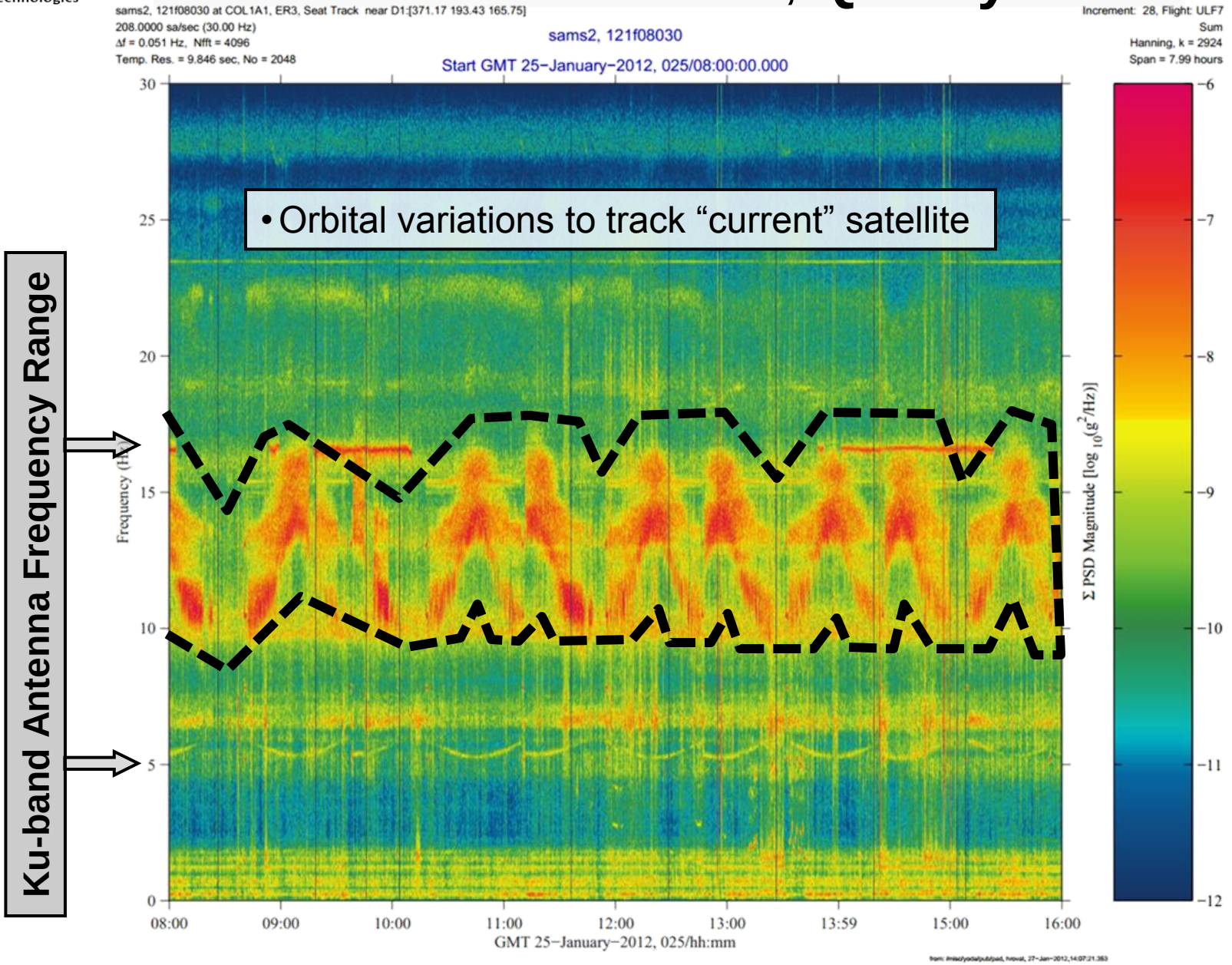
ZIN Technologies

Ku-Band Antenna, **Qualify**



ZIN Technologies

Ku-Band Antenna, **Qualify**



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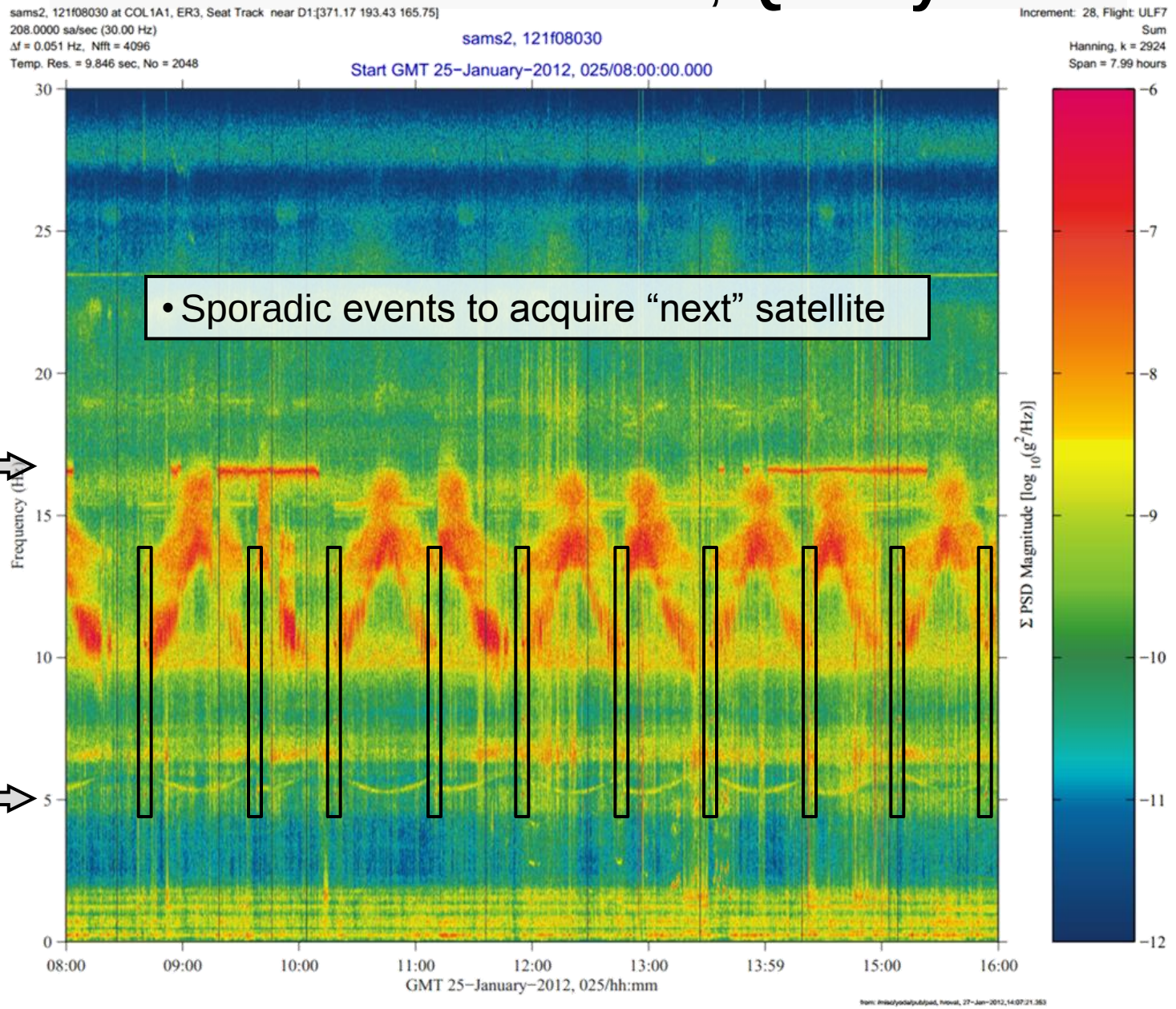
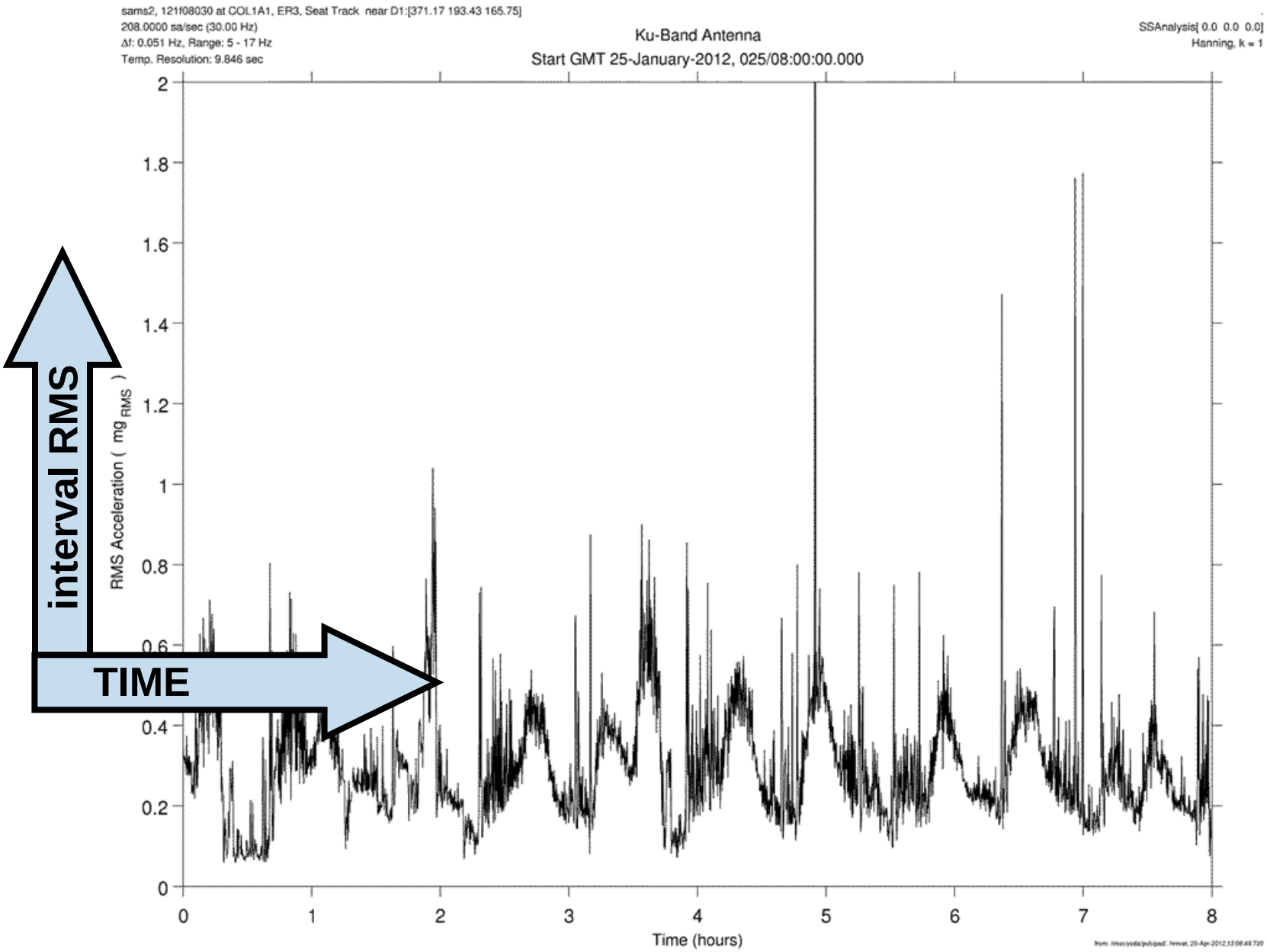


Ku-band Antenna Frequency Range

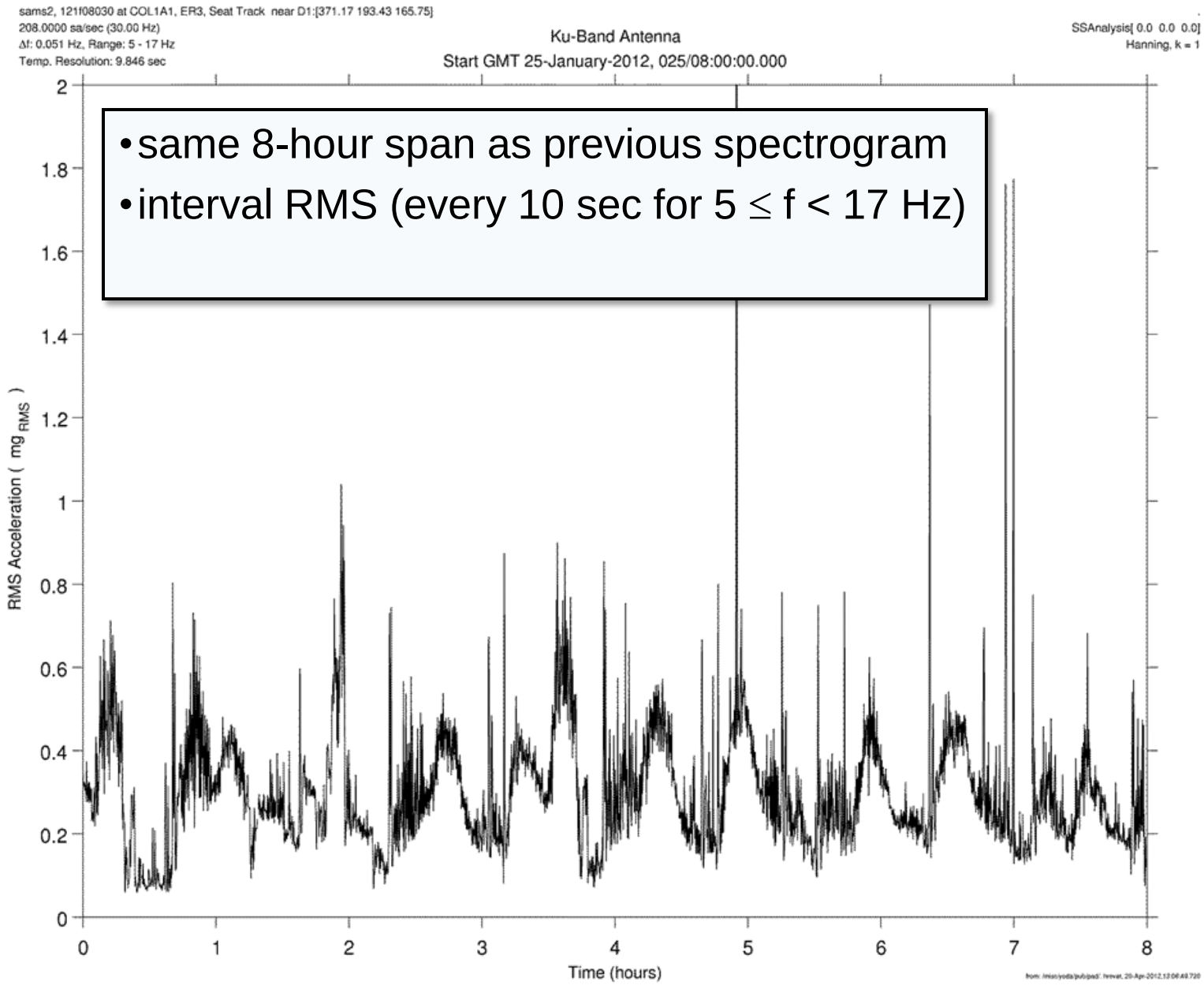
- Sporadic events to acquire “next” satellite

ZIN Technologies

Ku-Band Antenna, **Quantify**



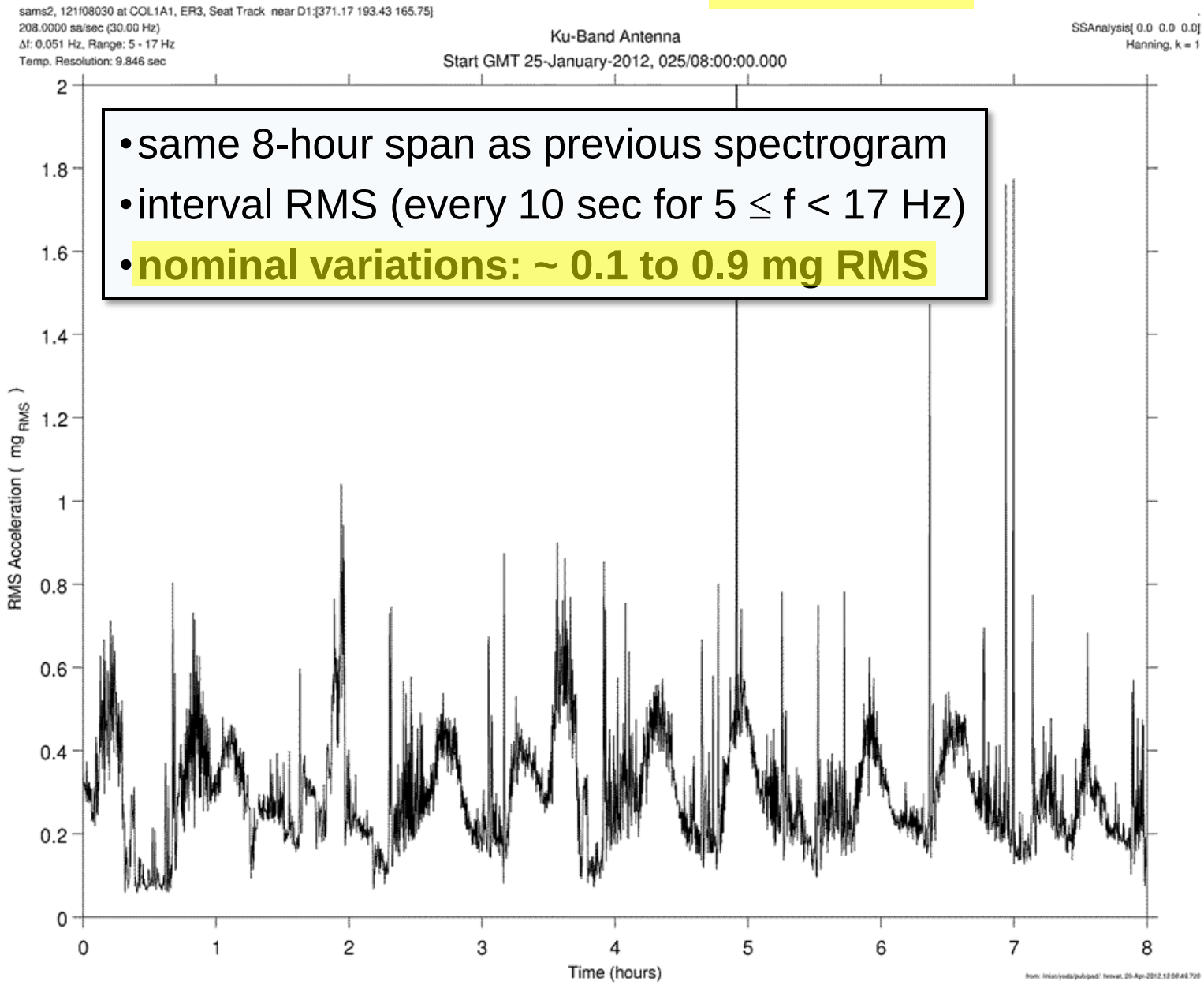
Ku-Band Antenna, **Quantify**



- same 8-hour span as previous spectrogram
- interval RMS (every 10 sec for $5 \leq f < 17$ Hz)

ZIN Technologies

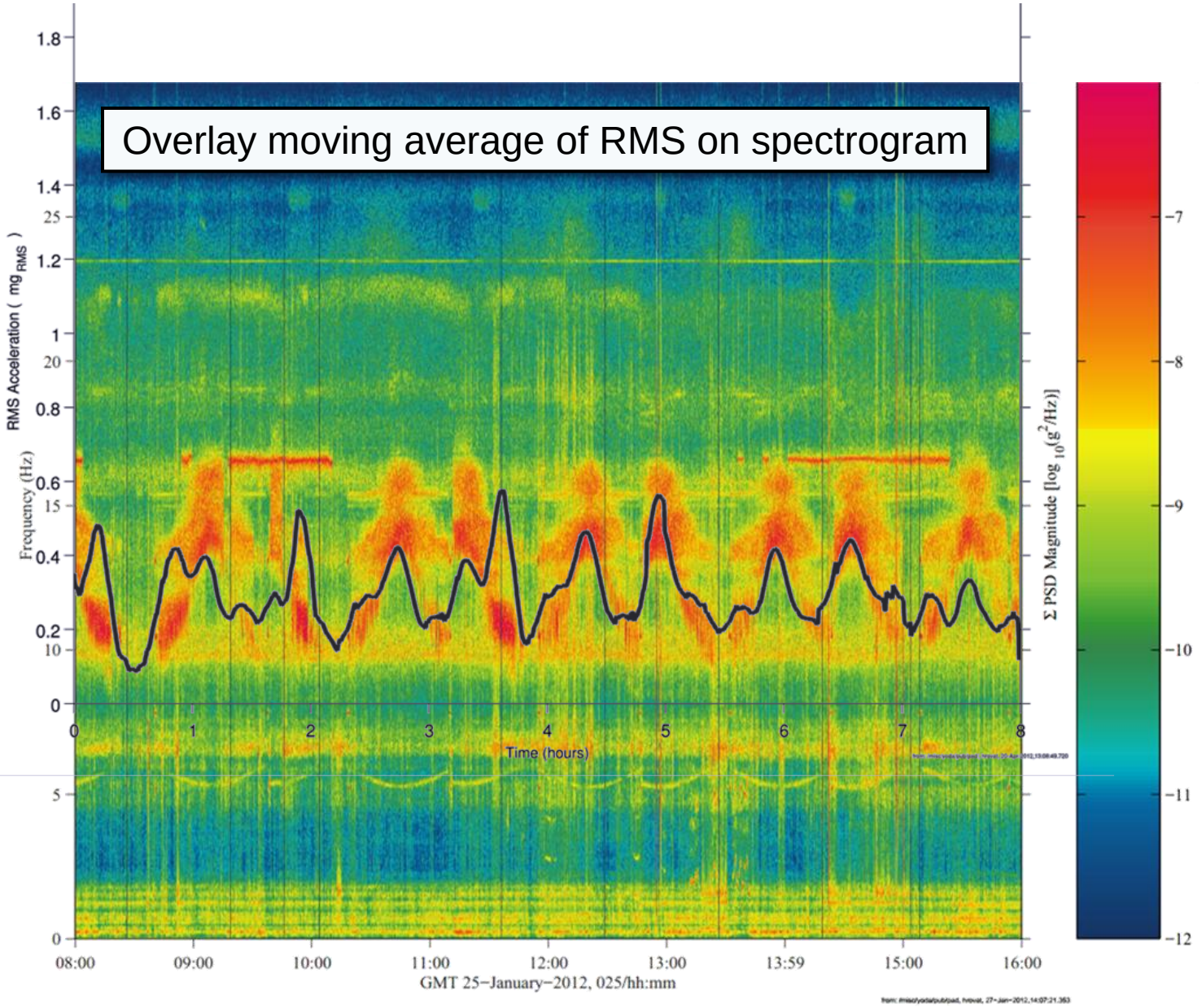
Ku-Band Antenna, Quantify



- same 8-hour span as previous spectrogram
- interval RMS (every 10 sec for $5 \leq f < 17$ Hz)
- **nominal variations: ~ 0.1 to 0.9 mg RMS**

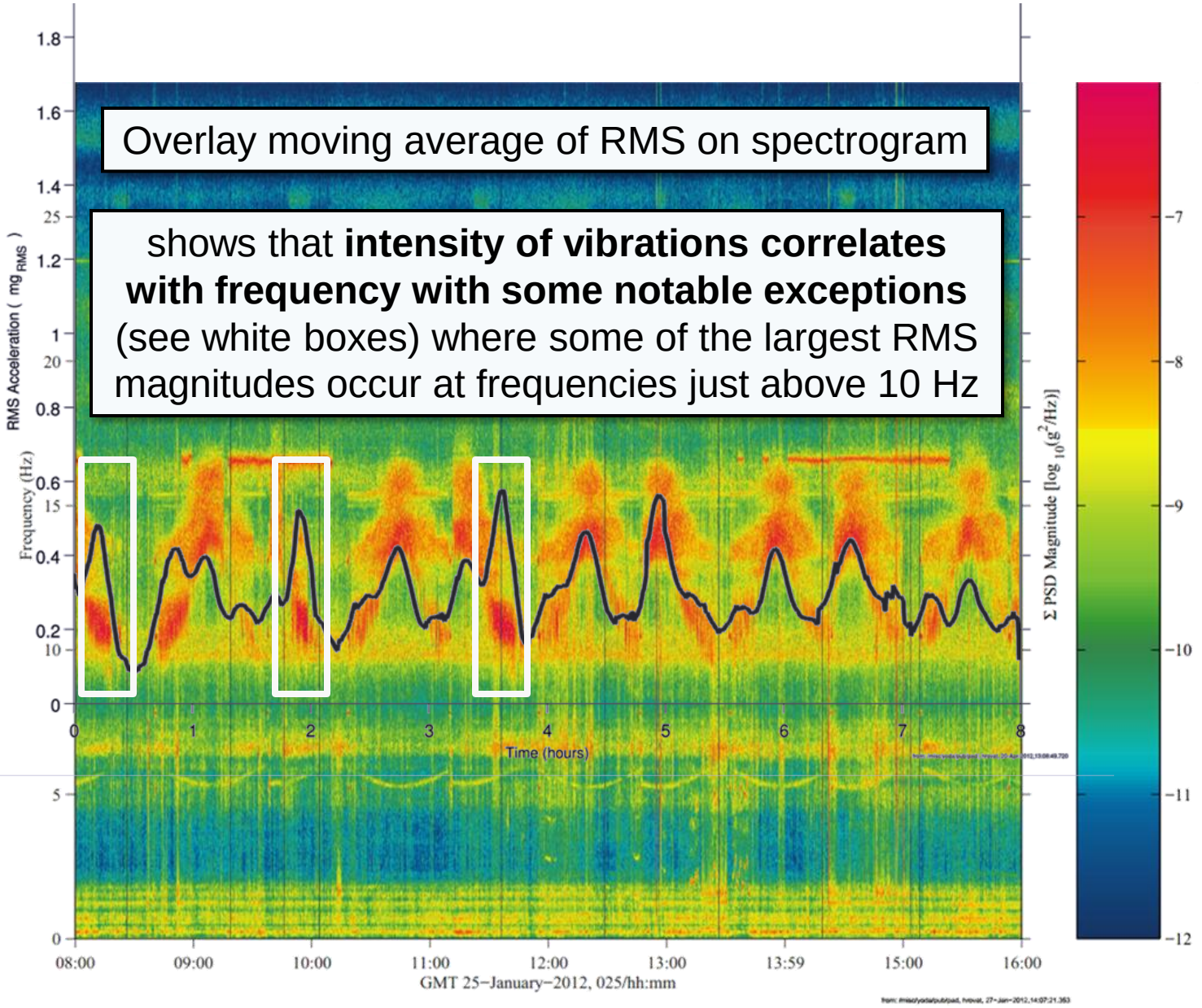
ZIN Technologies

Ku-Band Antenna, **Quantify**



ZIN Technologies

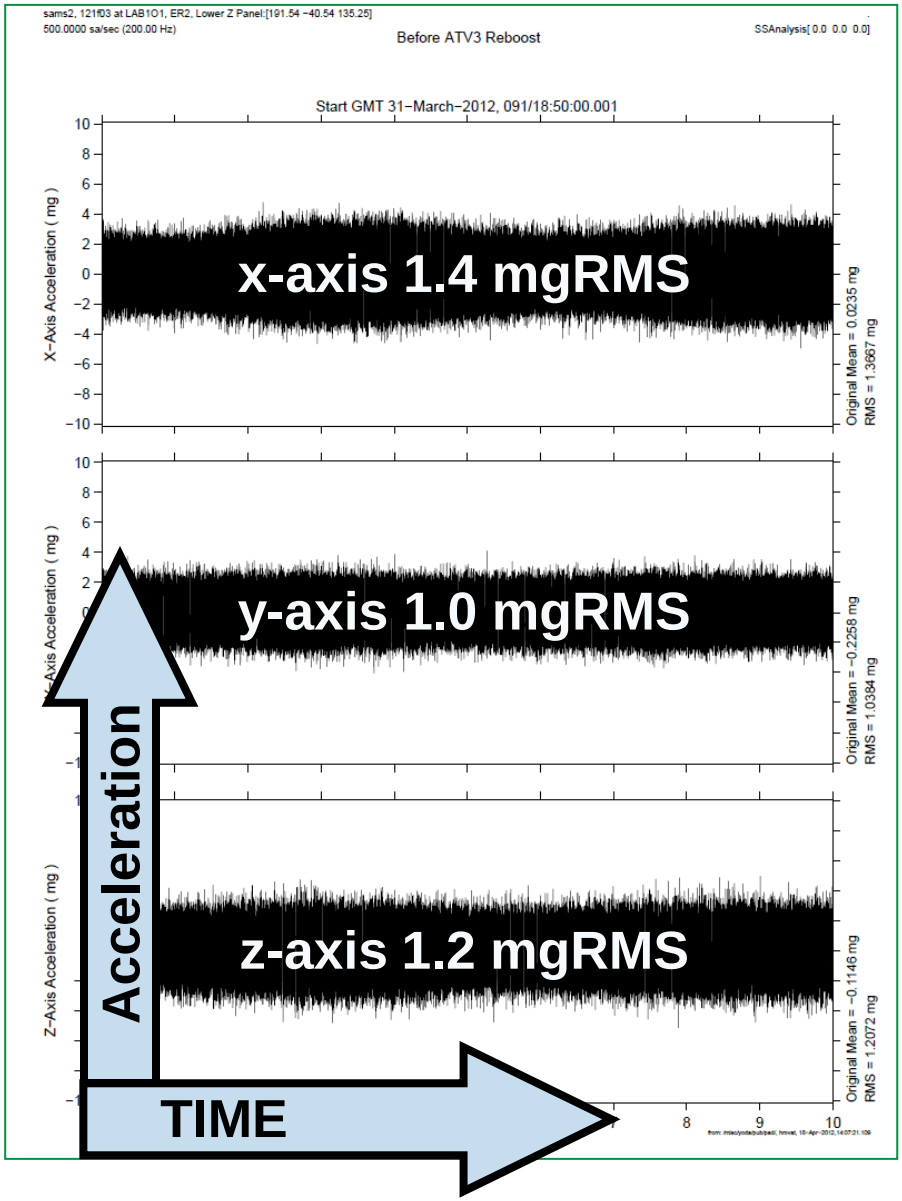
Ku-Band Antenna, **Quantify**



ZIN Technologies

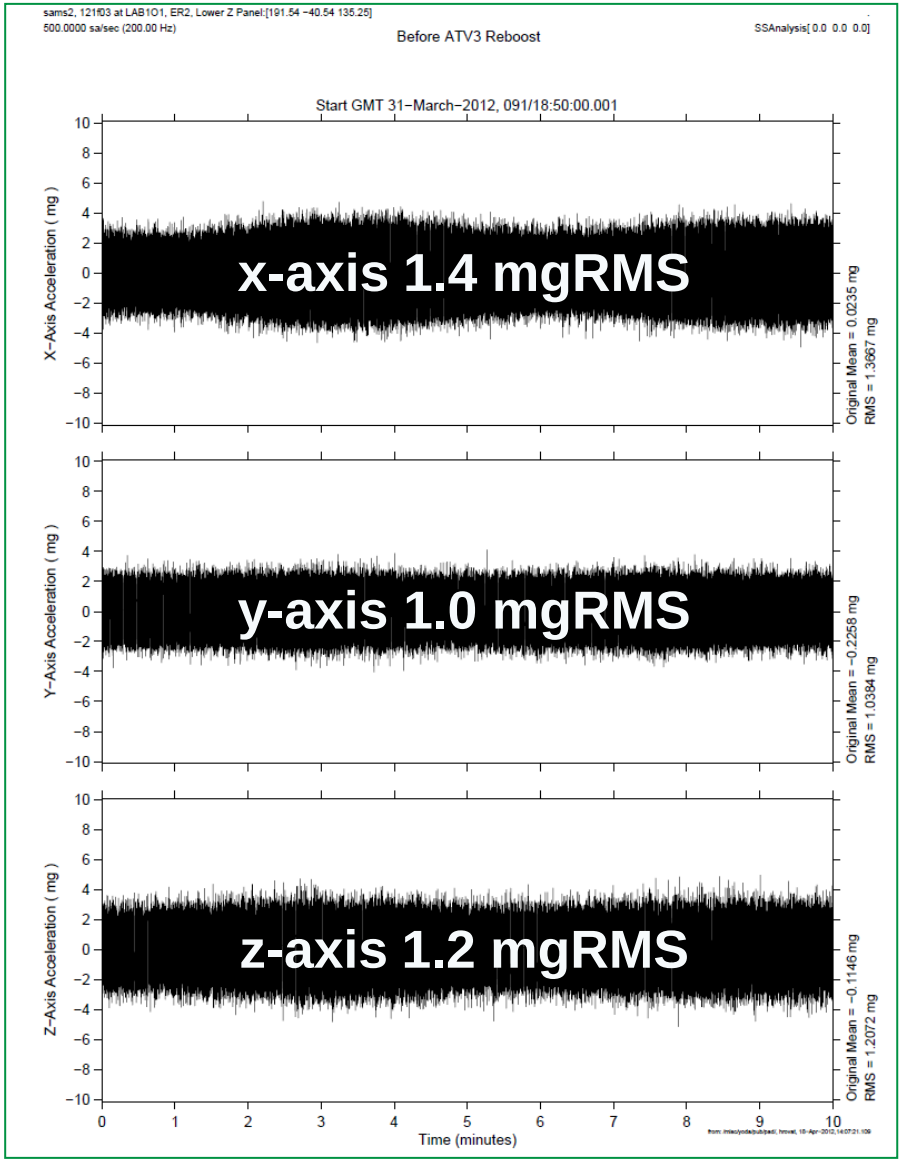
ATV3 Reboost GMT 31-Mar-2012

BEFORE

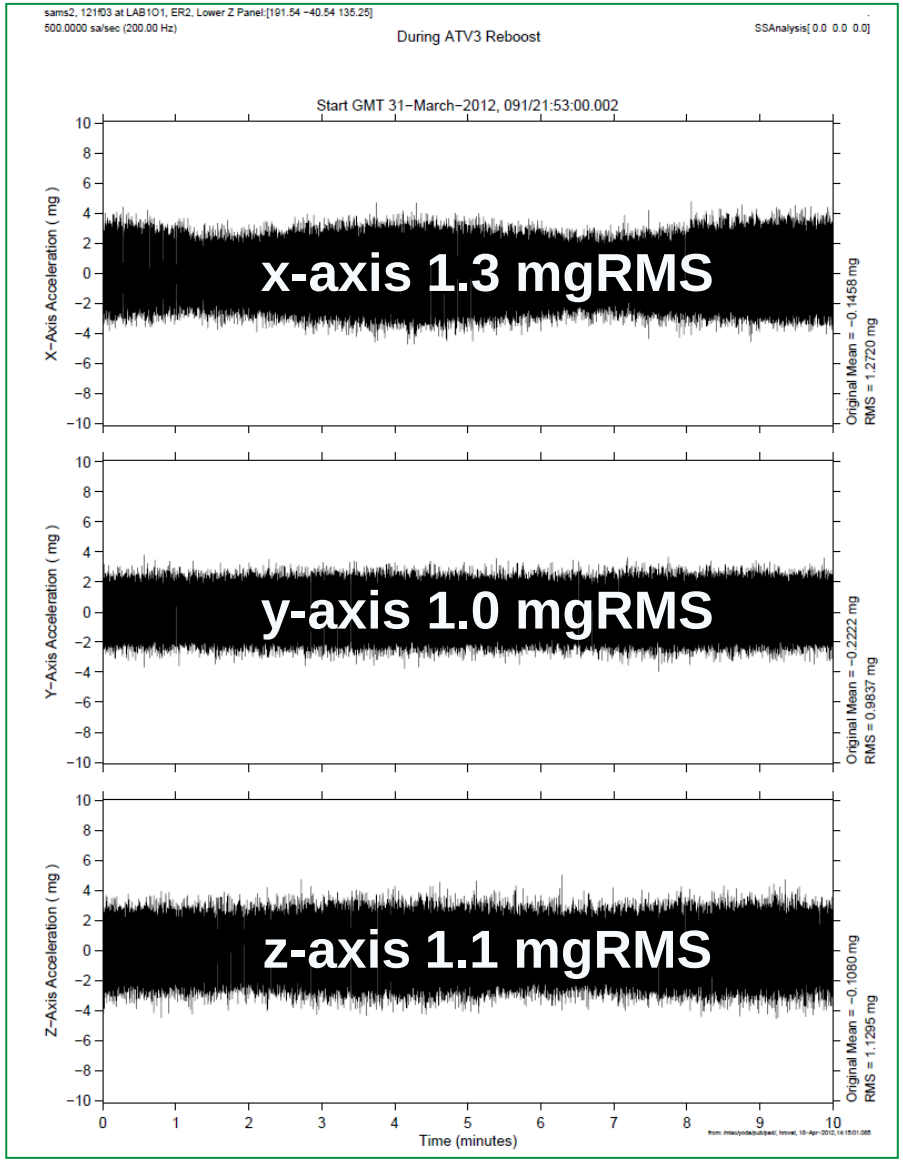


ATV3 Reboost GMT 31-Mar-2012

BEFORE



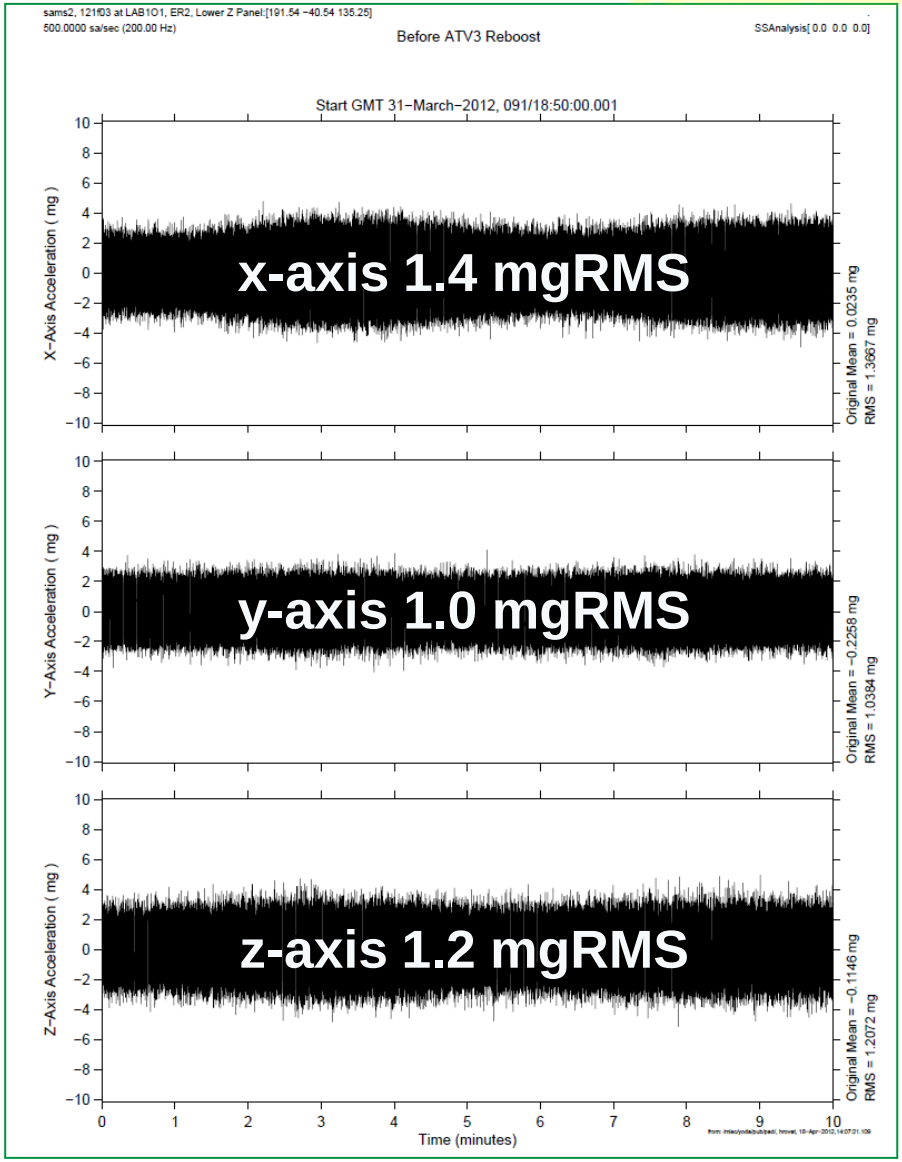
DURING

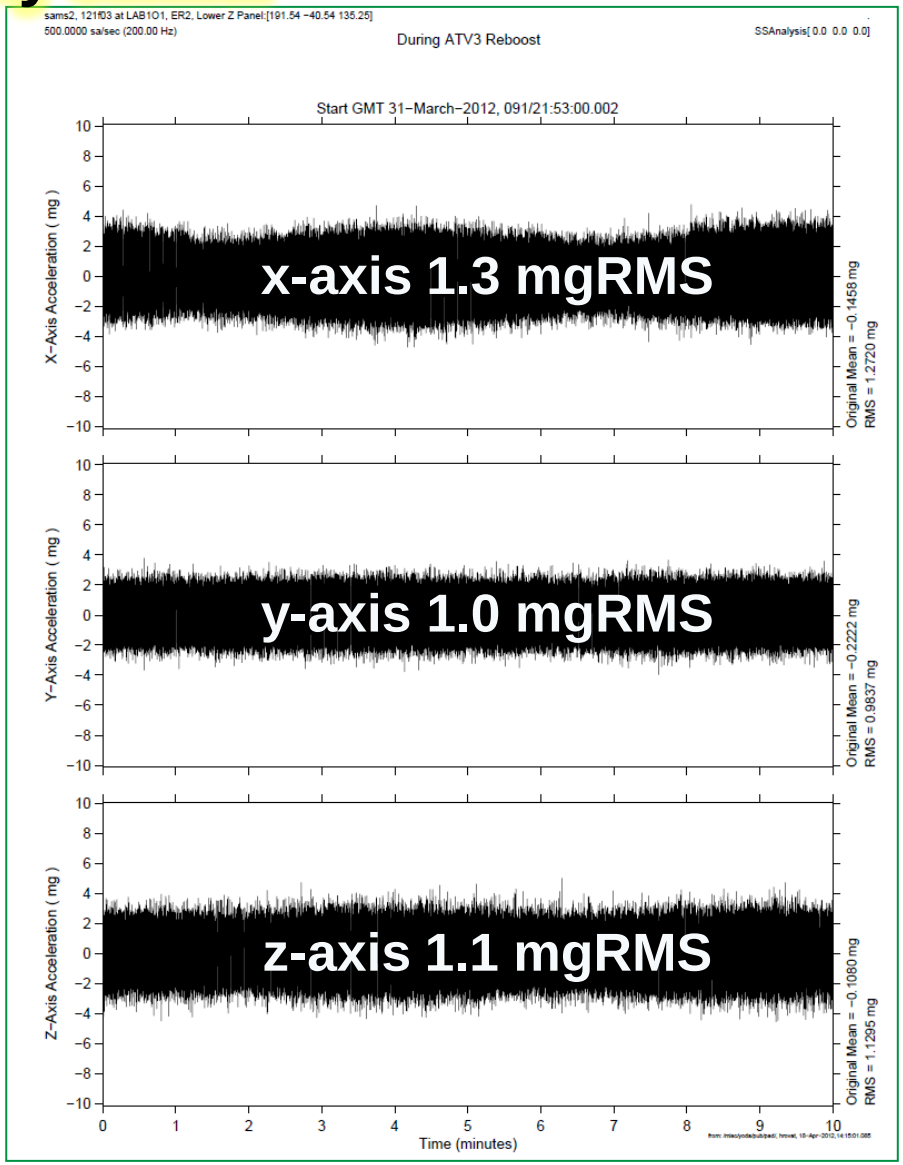


ZIN Technologies

ATV3 Reboost GMT 31-Mar-2012

BEFORE **remarkably similar** **DURING**

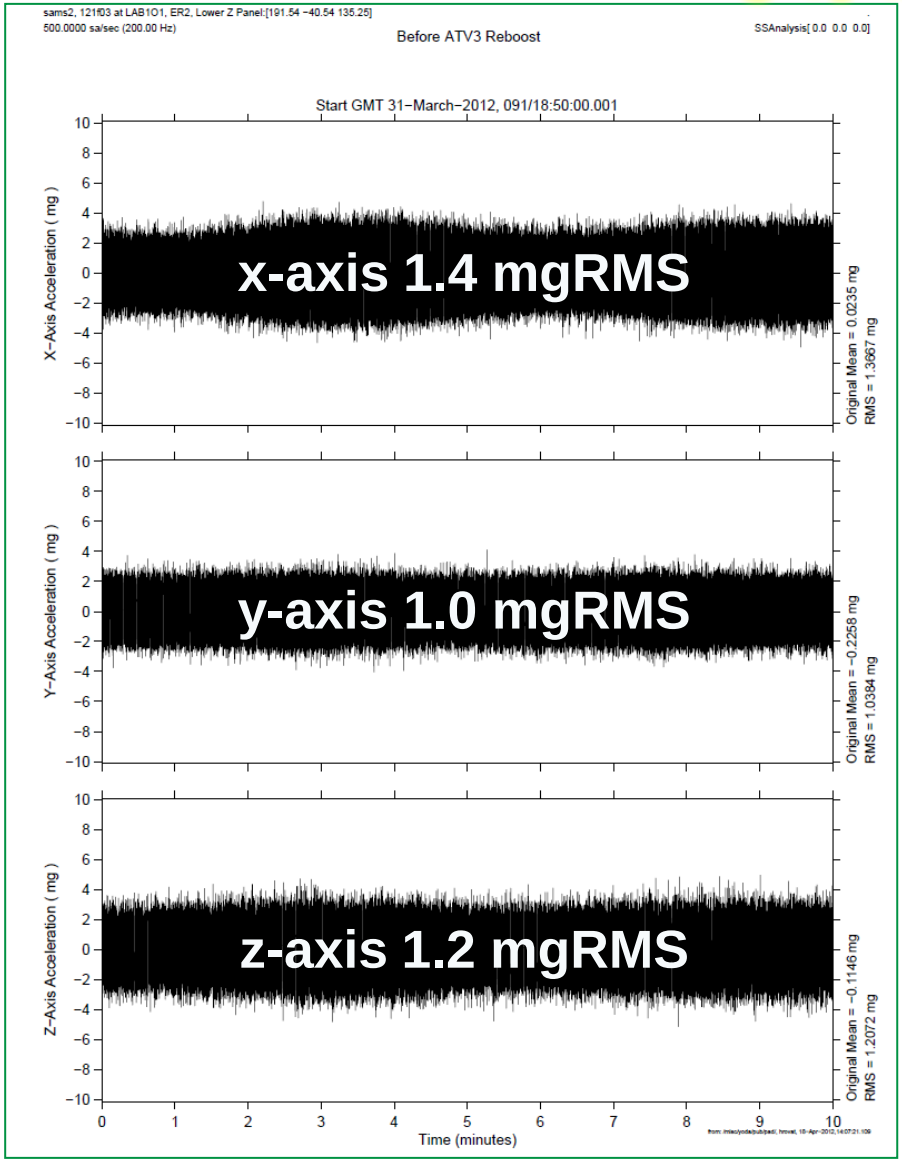


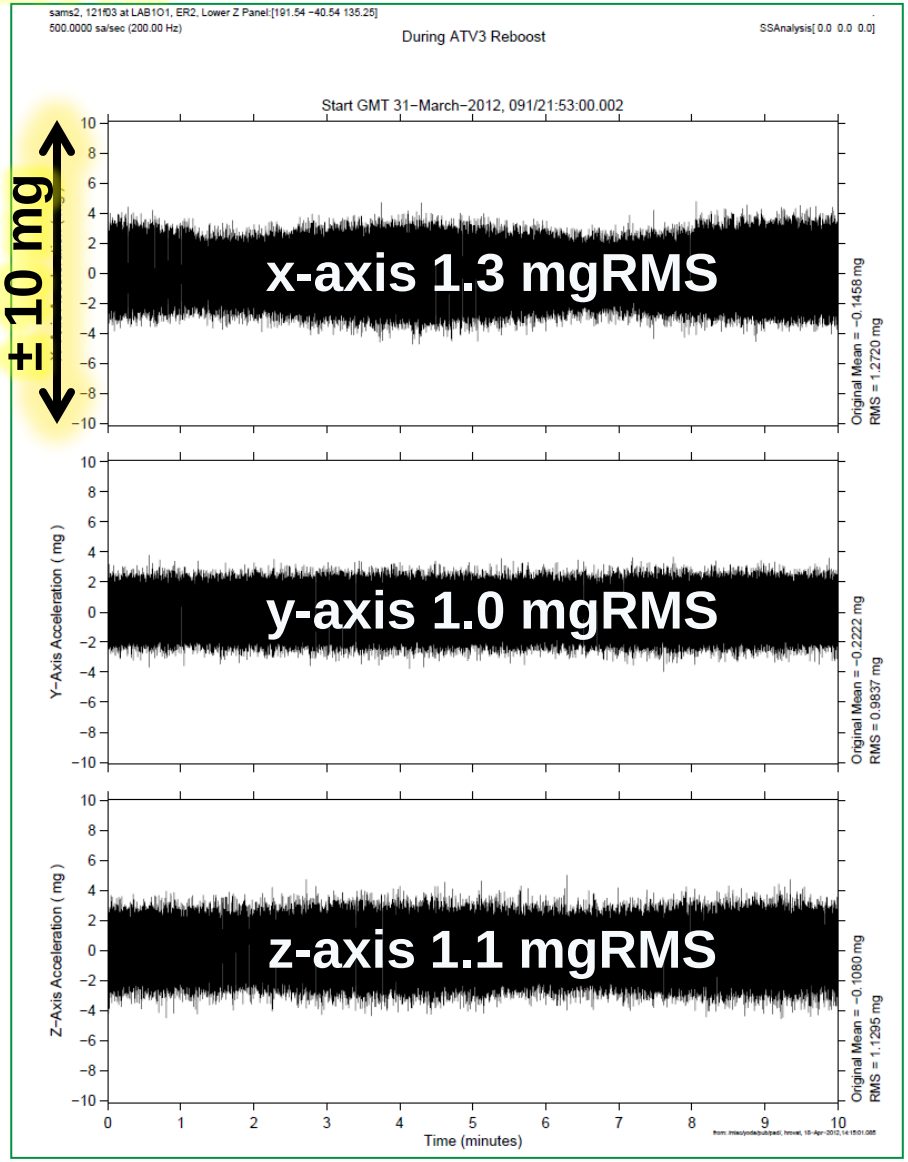


ZIN Technologies

ATV3 Reboost GMT 31-Mar-2012

BEFORE **0 < f < 200 Hz** **DURING**

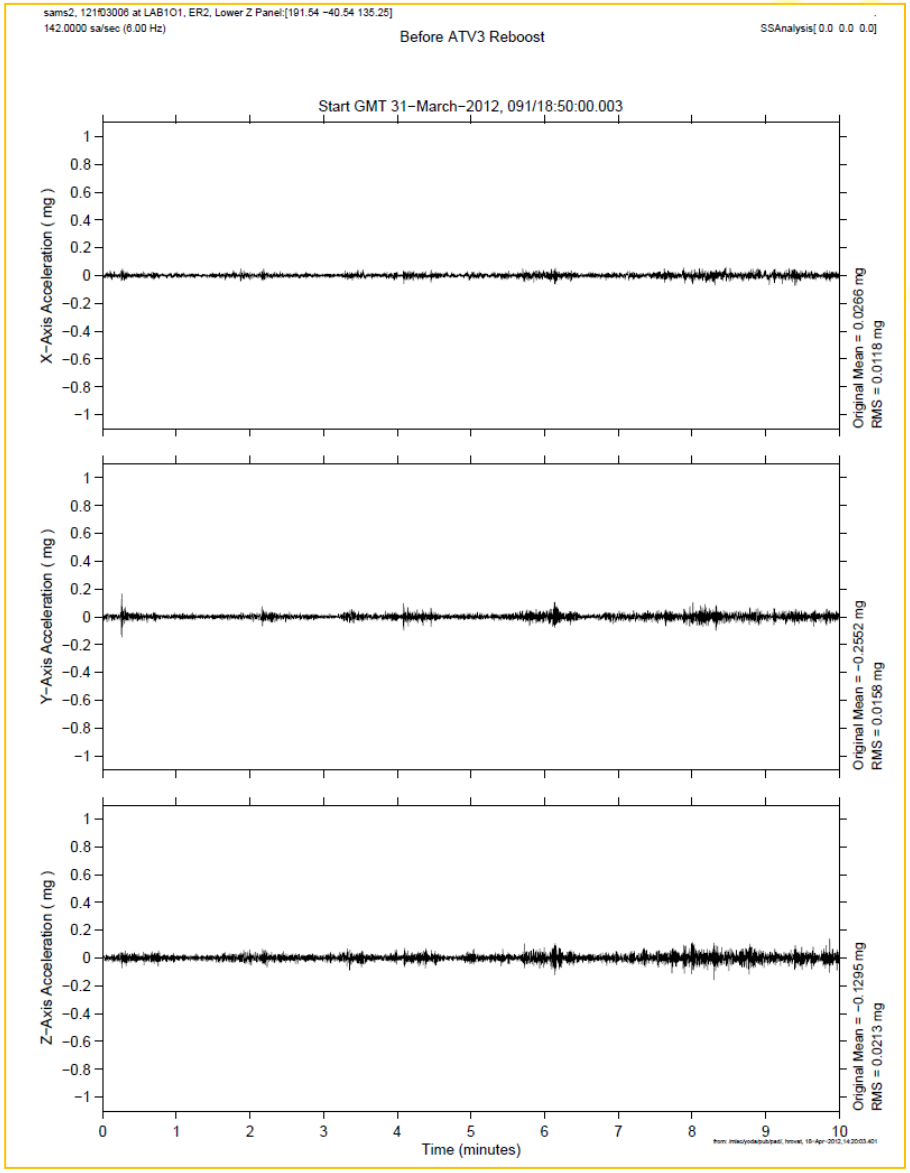


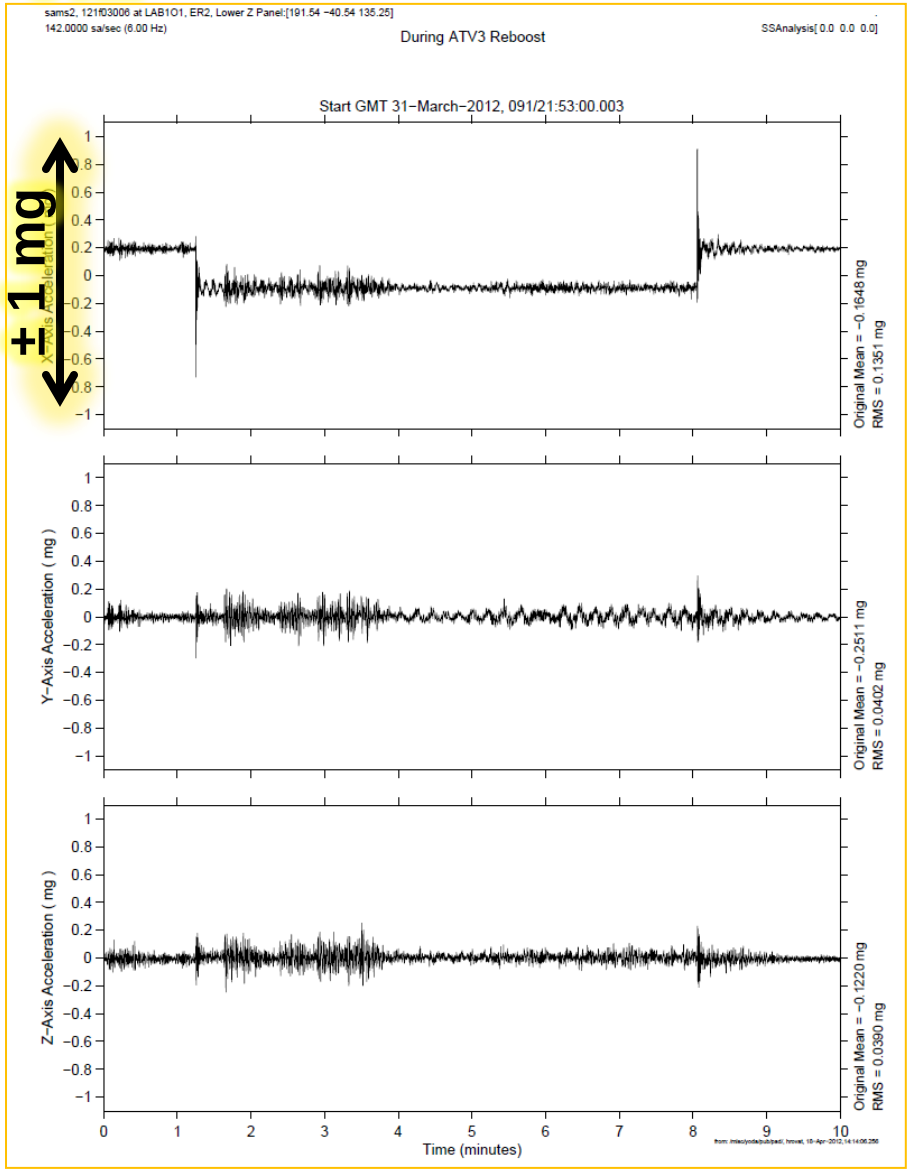


ZIN Technologies

ATV3 Reboost GMT 31-Mar-2012

BEFORE **0 < f < 6 Hz** **DURING**

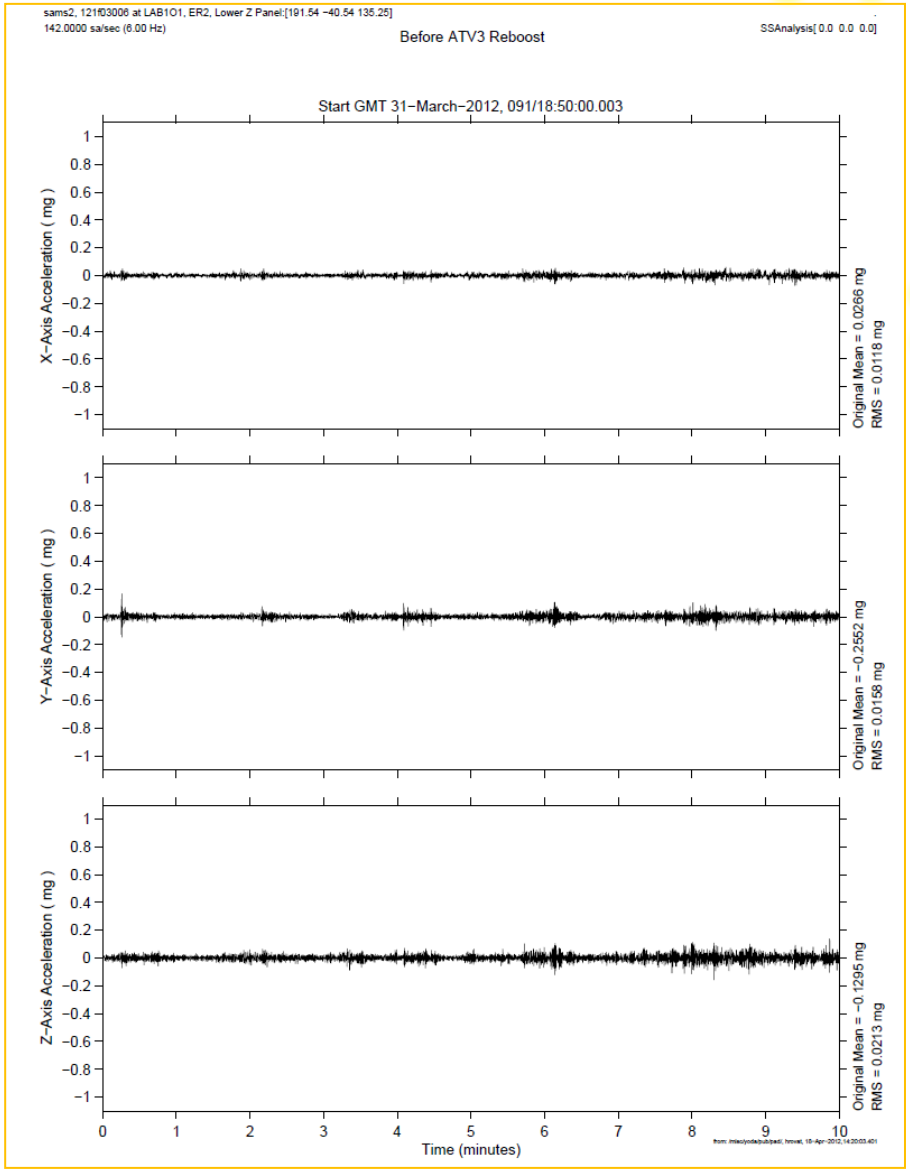


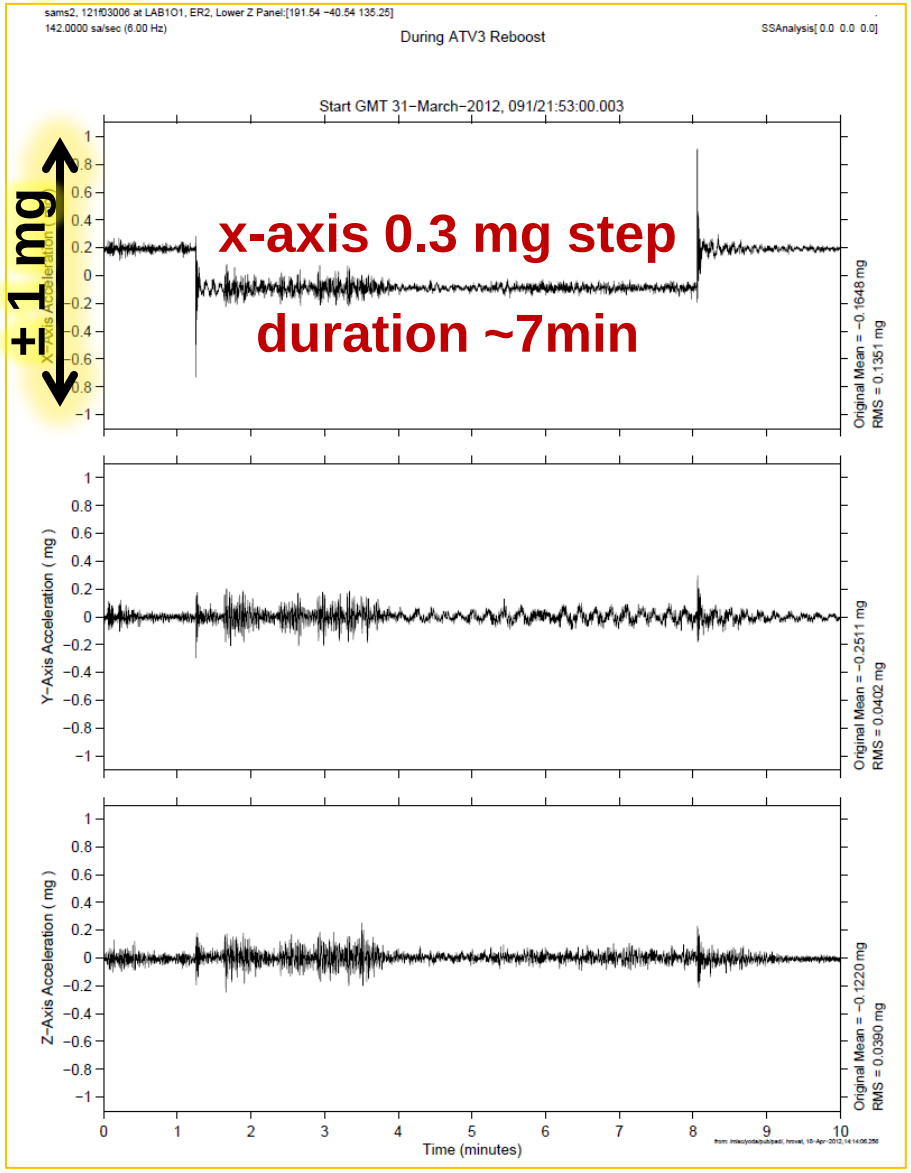


ZIN Technologies

ATV3 Reboost GMT 31-Mar-2012

BEFORE **0 < f < 6 Hz** **DURING**





ZIN Technologies

ATV3 Reboost GMT 31-Mar-2012

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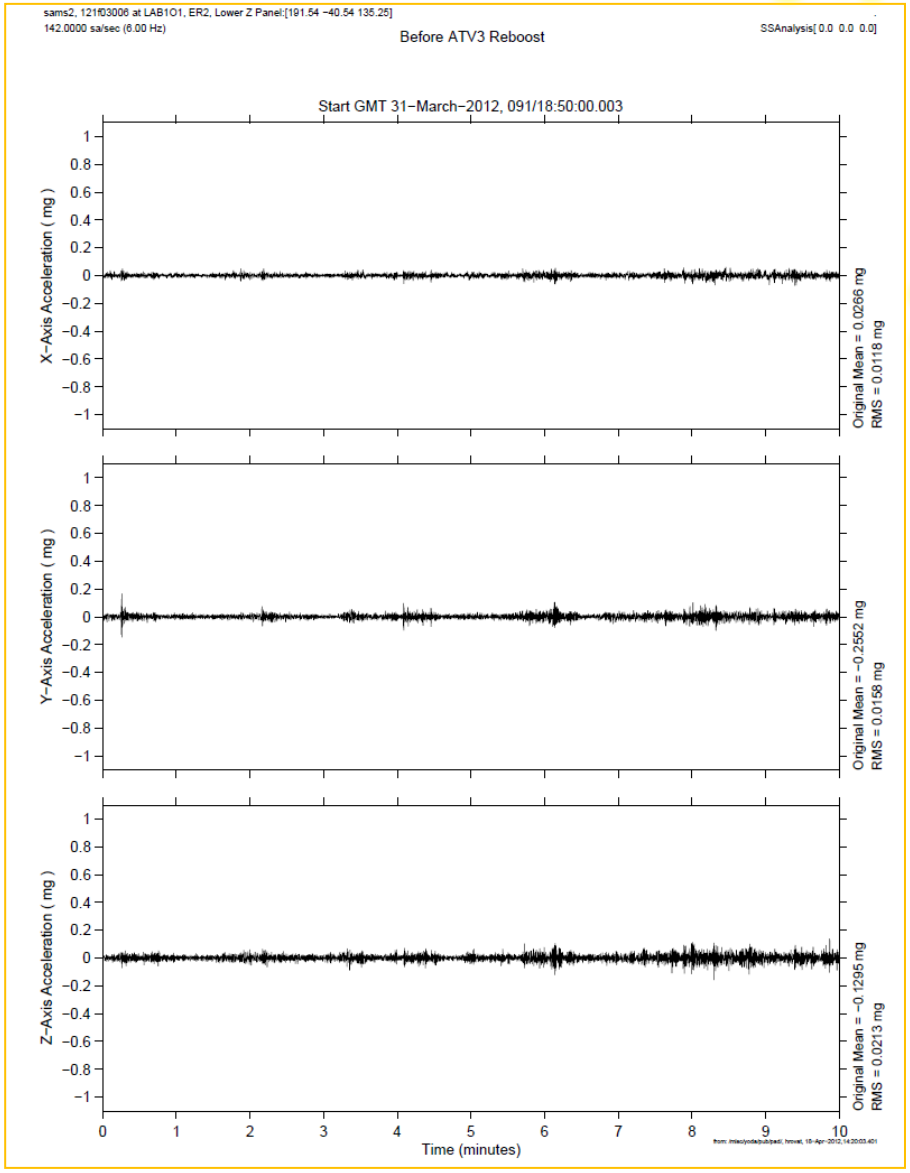
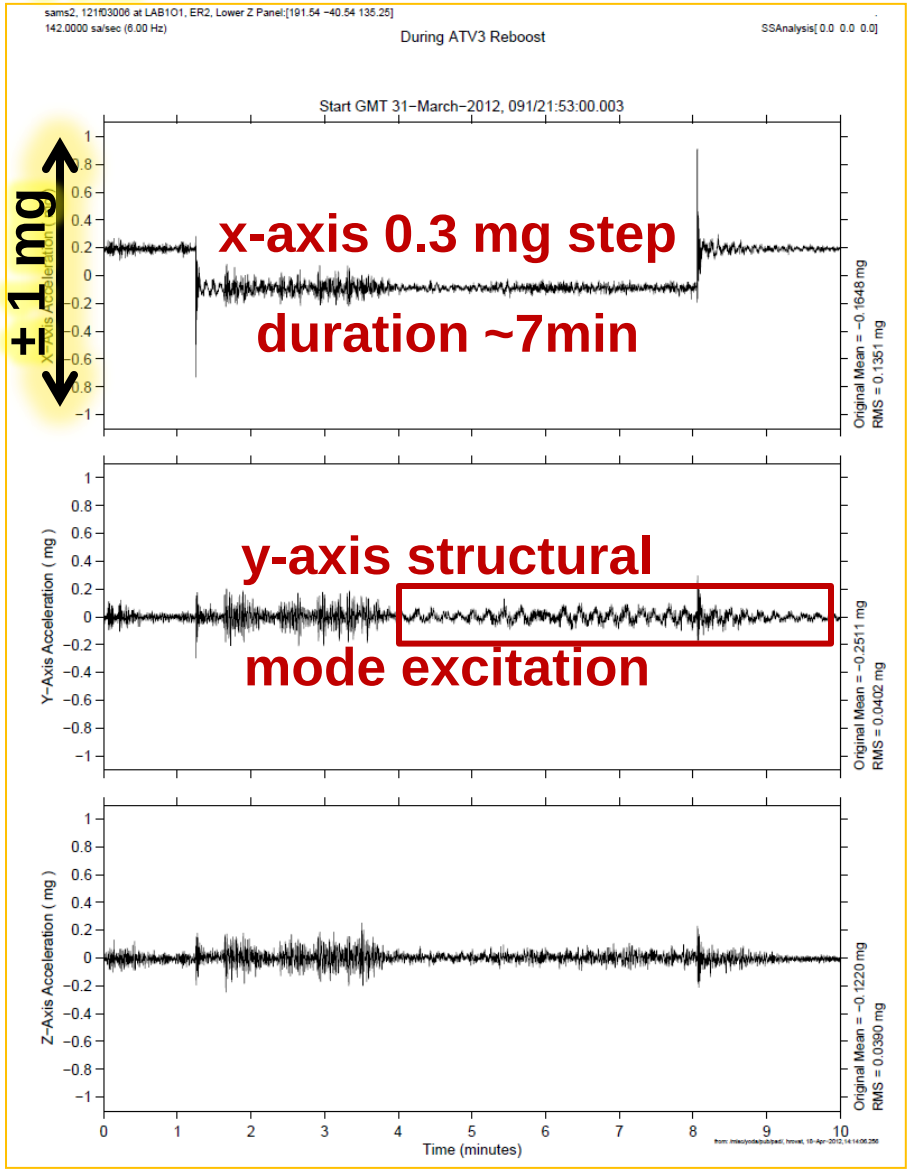
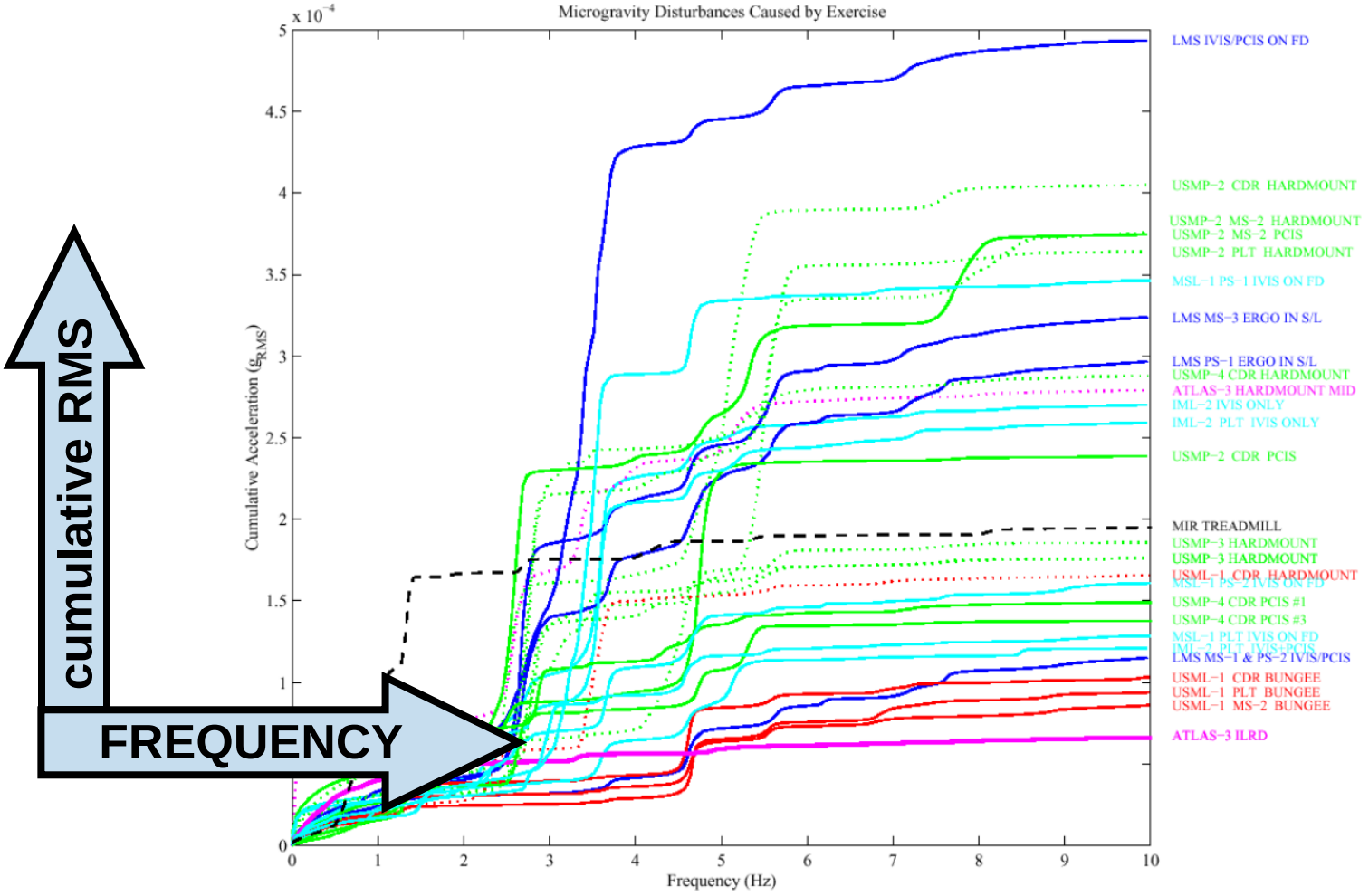




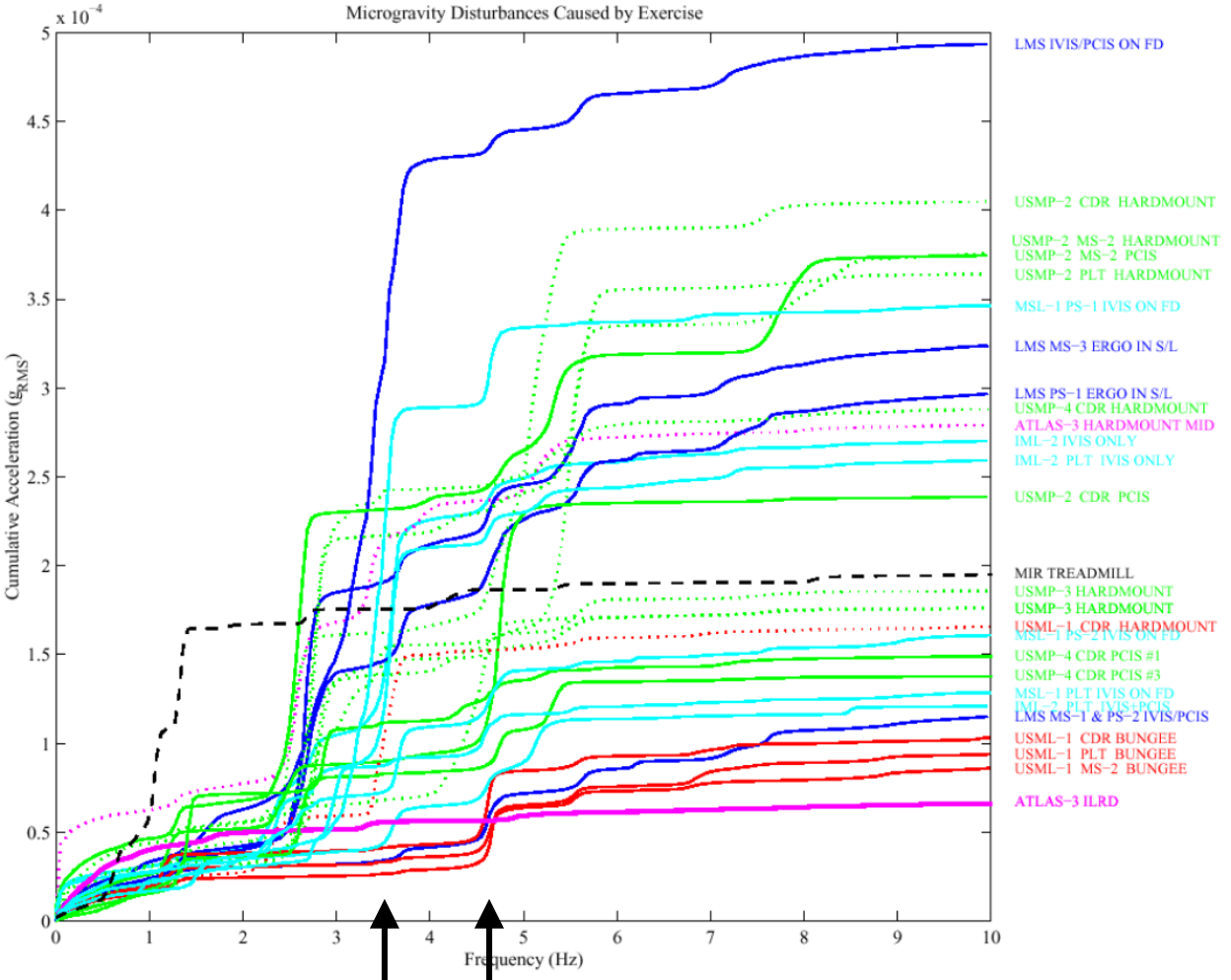
ZIN Technologies

Impacts/Crew Exercise: **Space Shuttle**



ZIN Technologies

Impacts/Crew Exercise: **Space Shuttle**



2 spectral peaks arise from shoulder sway & pedaling rate with excitation of Shuttle structural modes @ 3.5 and 4.8 Hz

Other Events and Disturbances

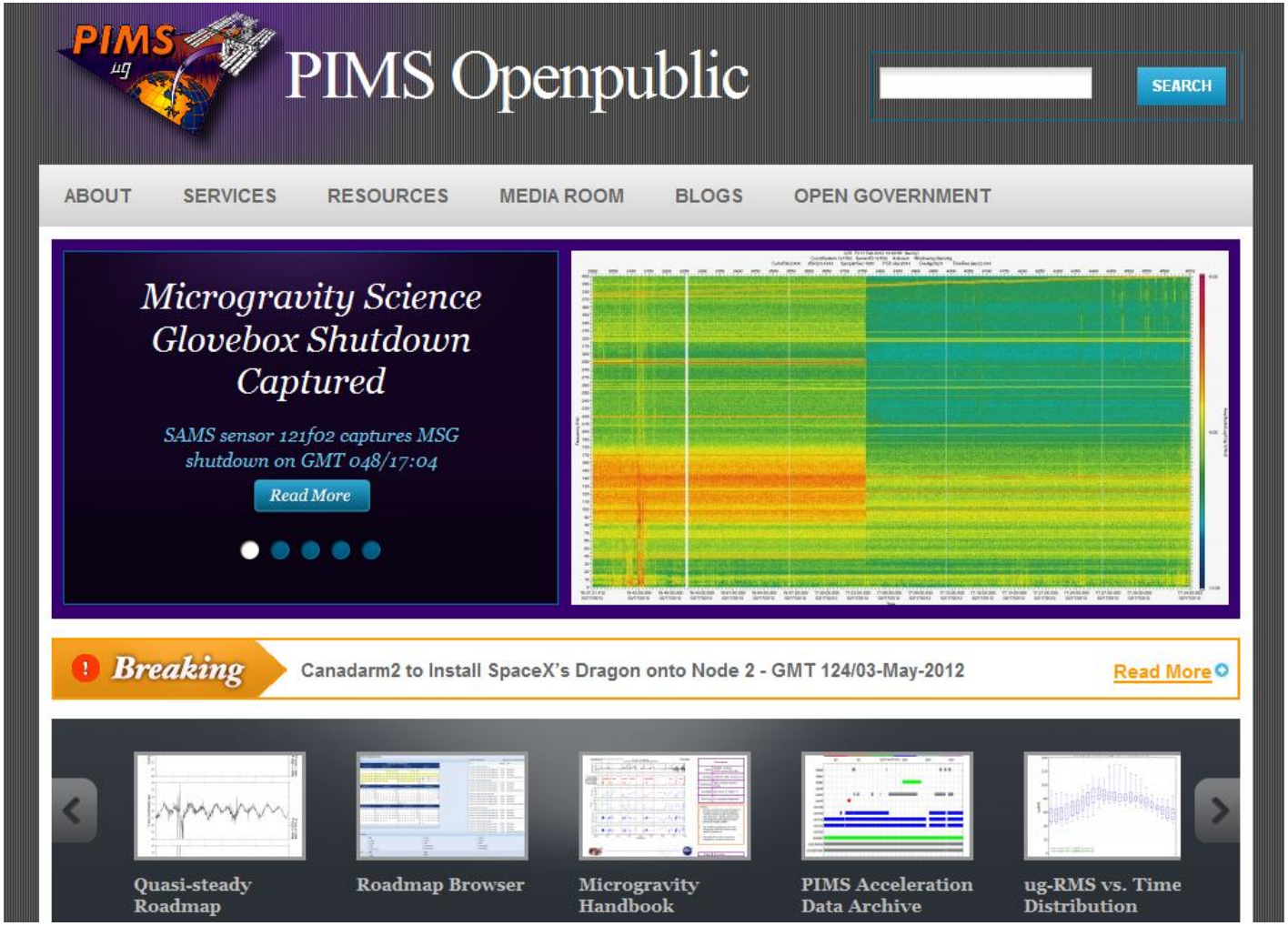
Event/Disturbance	Brief Characterization Notes
ATV1 Docking	impulsive event, 13 mg peak acceleration vector magnitude
ATV3 Reboost	x-axis step 0.3 mg, 7 minutes, y-axis structural excitation
CCAA	fan: ~57 Hz or ~95 Hz, step 510 ugRMS water separator: ~98 Hz, step 234 ugRMS
GLACIER Ops	two narrowband peaks: (1) 60 Hz, step 162 ugRMS, (2) 120 Hz, step 112 ugRMS
Ku-Band Antenna	5-17 Hz, 0.1 to 0.9 mgRMS orbital variations
MSG Ops	broadband, step 536 ugRMS
Progress Reboosts	mean values: t = 11.4 minutes, **Δ**Ax = 0.4 mg, **Δ**Vx = 2.36 m/s N = 24 (reboosts)
Robonaut Ops	narrowband, 47 Hz, step 50 ugRMS
ARIS Attenuation	*publication*: Fluids Integrated Rack (FIR) ops
Crew Exercise	*publication*: CEVIS, Velo, ARED, T2
Crew Sleep/Wake	*publication*: difference primarily below about 6 Hz
PaRIS Attenuation	*publication*: Combustion Integrated Rack (CIR) ops
SARJ Stops Rotating	*publication*: high solar beta angle, structural dynamics change

Plans to participate in…

Open Government Initiative

TRANSPARENCY • PARTICIPATION • COLLABORATION

OPEN GOV



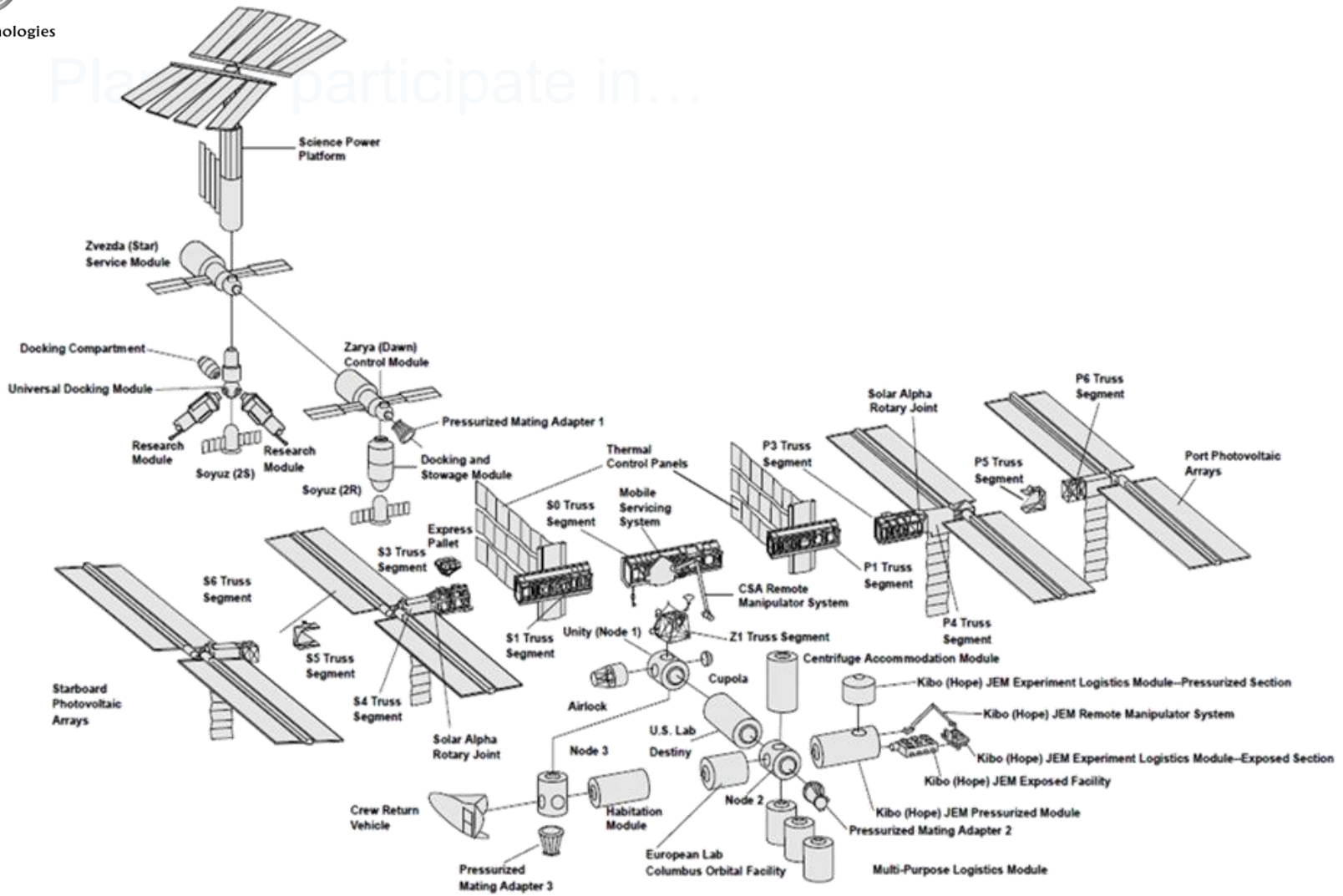


Figure 2-1 International Space Station at Assembly Complete

PIMS ISS Increment-6/8 Microgravity Environment Summary Report:
November 2002 to April 2004